HOW TO FLY

BARRETT STUDLEY

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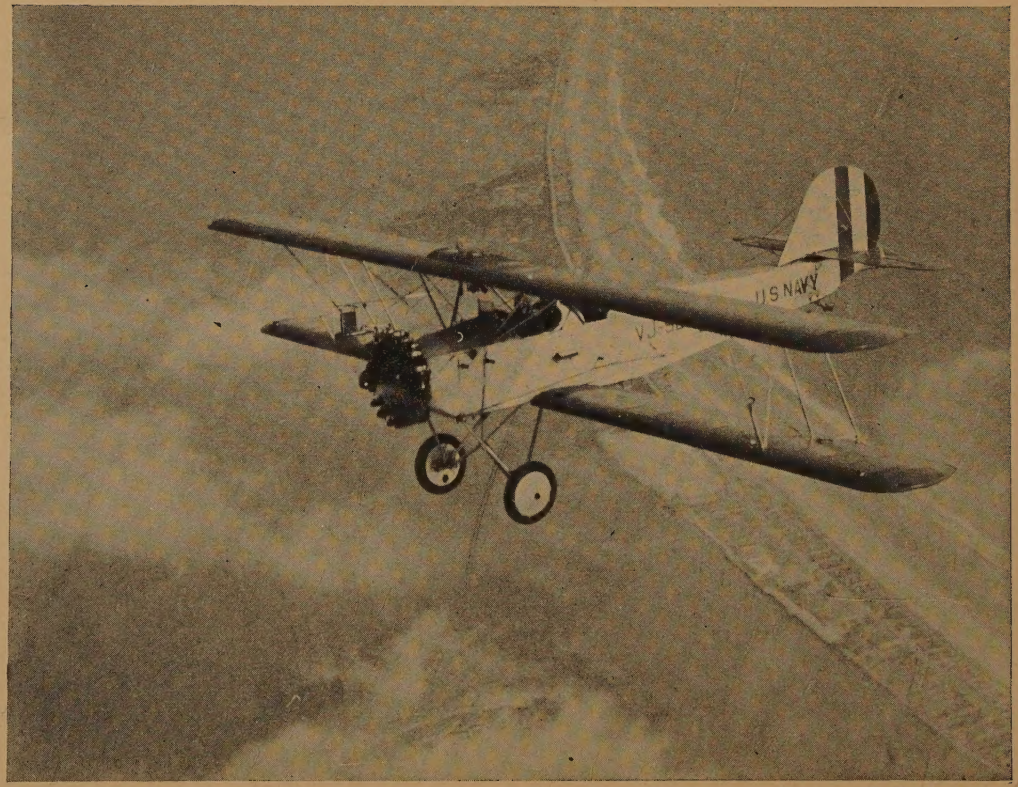
HOW TO FLY

By

LIEUT. BARRETT STUDLEY

PRACTICAL FLIGHT TRAINING

HOW TO FLY



U. S. Navy photo.

A training plane in flight.

HOW TO FLY

The Pilot and His Problems

BY

LIEUTENANT BARRETT STUDLEY

UNITED STATES NAVY

NEW YORK

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FOREWORD

How to Fly is a development from the *Flight School Manual* of the Naval Air Station at Pensacola, Florida, originally written in 1926 by the present author and adopted for use of students there. The subject matter of the *Manual* was later expanded and revised for general use in flight schools, and was published in 1928 under the title of *Practical Flight Training*. This book was intended primarily for the use of students actually under instruction, and was consequently prepared as a detailed technical analysis of flight training.

The aim of the present volume is to describe in a non-technical way the problems met in learning to fly. It is, of course, based on the same fundamental principles as the two earlier works. But only the more immediate and practical details of their application have been included, and these are presented in non-technical terms. Every effort has been made to depict maneuvers simply and clearly. And the significance of different requirements is illustrated in various cases by accounts of actual occurrences which have come within the observation of the author. It is hoped that anyone who is interested in aviation may find here a satisfactory explanation of the practical problems of flying.

BARRETT STUDLEY,
Lieutenant, United States Navy.

Naval Air Station,
Pensacola, Florida.
October, 1929.

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CHAPTER I

PIONEERS OF THE AIR

THROUGHOUT historical time, the conquest of the air has occupied a place in man's dreams. The legendary Dædalus of ancient Greece is the hero of a fable of waxen wings. To escape from the island of Crete, he was supposed to have contrived wings for himself and his son, Icarus. With these, they rose into the air and soared out over the sea. But Icarus in his exultation flew too high and approached the sun. Its heat melted the wax and he fell into the sea.

For many centuries, however, human flight was limited to such tales. No actually serious attempts were made to fly. In the fifteenth century, Leonardo da Vinci, the great Italian artist and physicist, drew up plans for an ornithopter, a machine which was to sustain itself by flapping its wings like a bird. But the project never progressed beyond the theoretical stage. Darius Green and his famous flying machine represent the aviation of that time. For, having constructed his wings with only a desire to fly instead of a knowledge of aerodynamics, his take-off from the top of a barn resulted in an immediate and disastrous descent.

It was in the year 1783 that men first actually rose into the air. The flight was made in a hot-air balloon built by the Montgolfier brothers in France. Taking off from the Bois de Boulogne in Paris with two passengers in the pres-

ence of a great crowd of spectators, this first aircraft ascended to an altitude of 3000 feet and crossed the Seine. It was sustained by the heating of the air in its bag, forty feet in diameter and seventy feet high. The air was kept hot by a fire at the bottom of the bag, which was fed with straw by the passengers.

Only a few days thereafter the forerunner of modern balloons took the air. This was a large spherical bag inflated with hydrogen. Built by Professor Charles, it also took off from Paris with two passengers. It rose to 1800 feet, at which altitude it was kept by the use of a gas valve and ballast. This demonstration of the lifting power of a light gas as a sustaining force for airships resulted in the development of lighter-than-air aviation. Balloons were a common sight before the first practical airplane had even been conceived.

The earliest use of wings for purposes of human flight was in the construction of gliders, motorless machines which took off from the top of a hill and soared downward. Successful flights were made as early as 1810 by Sir George Cayley, an Englishman. He was a careful, thorough observer, and his experiments did much to lay the foundation of the science of aerodynamics. Others carried on the work, which culminated in the flights of Otto Lilienthal, a native of Pomerania. Lilienthal studied the actions of young storks just learning to soar and noted that they always took off and landed headed into the wind. He built a glider with a single wing and a tail. Then, following the example of the birds, he ran down a hill facing the wind. His efforts met with much success. Many flights were made, sometimes covering as much as a quarter of a mile. On several he succeeded in soaring to a height actually greater than that of his starting point.

In America, experiments with gliders were meanwhile being carried on by Chanute and Herring. In order to attain greater stability in the air, they gave their machines several wings, one above another, varying in number from two to five. These wings were braced by struts and wires, much as present-day biplanes are. They made many successful flights.

But it is to Hiram Maxim, another American, that the credit goes for first designing a power-driven heavier-than-air machine which actually lifted men from the ground. His airplane definitely proved that it was capable of sustaining itself by means of the lift of its wings as they moved through the air. Only the fact that it was not free, but was restricted by guard rails, kept its inventor from attaining the distinction later gained by the Wright brothers.

Maxim's plane was a huge craft, weighing four tons. The area of its wings was much greater than that of any but the largest of modern airplanes. It was steam-driven, carrying a boiler which supplied power for its engines. In order to permit it to gain the speed necessary to leave the ground, the plane ran on a track of steel rails half a mile long. It was Maxim's desire to test it out thoroughly before attempting an actual flight. Consequently he added to the track guard rails above the wheels, to keep it from rising more than a few feet into the air.

Several experimental runs were made in which the speed was insufficient. Finally, on July 31, 1894, the boiler pressure was increased to its maximum capacity, and, with three passengers aboard, the plane started down the track. As speed was gained, the wheels lifted from the rails. The plane had raised its own weight and that of its passengers by its own power. Its wings alone were sustaining them. It was flying. Nothing but the guard rails restricted it.

But its success was greater than its inventor's calculations had anticipated. The lift of its wings proved to be in excess of the strength of its axles. The rear axle carried away, and the tail of the machine swung up into the air. A few seconds later one of the front wheels also tore loose from its guard rail. Then the steam was shut off, and the machine fell back onto the ground, off the rails.

Maxim had proved definitely that a machine could be constructed which would rise into the air by its own power. Had he been able to go on, it is likely that he might have been the first man to fly in an airplane. But the plane had been damaged when it jumped the track. And unfortunately he lacked the funds necessary to continue his experiments. Hence he was forced to give up the project.

A few years later another man came equally close to solving the problem of power-driven flight. This was Professor Samuel P. Langley of the Smithsonian Institution, who had begun his study of aerodynamics fifteen years previously. He had constructed a number of model airplanes which had flown successfully. One of them, with a one-horsepower engine, had covered a distance of three-quarters of a mile. Finally in 1903 he built a large machine driven by an engine of 50 horsepower. His calculations indicated it to be capable of sustained flight with passengers. But the problem of launching it proved insoluble at that time. On each of two attempts to take it into the air, the launching apparatus failed to function properly and the plane was wrecked. It is interesting to note, however, that a number of years later this plane was rebuilt exactly in accordance with Langley's plans and that, with a modern engine and landing gear, it was successfully flown. Consequently the distinction may be claimed for its inventor that he con-

structed the first heavier-than-air machine which eventually flew by its own power.

With the secret of flight so closely approached, it was inevitable that it should be gained. To the Wright brothers goes the credit for reaching the goal. They were the first to build a machine in which were combined all the factors necessary for power-driven, controlled flight. And in this machine they were the first men actually to leave the earth in free flight sustained by wings.

Orville and Wilbur Wright were born in Dayton, Ohio, where, in the last decade of the nineteenth century, they kept a bicycle repair shop. They were interested in aeronautics and had experimented with kites and with small model airscrews rigged as helicopters. The accounts of the successes of Lilienthal and Chanute with gliders reached them and turned their attention to this type of machine. In searching for a place where they would find steady winds, they were advised by the Weather Bureau to go to the North Carolina coast. Accordingly in 1900 they established themselves at Kitty Hawk, just north of Cape Hatteras.

During the succeeding three years the Wrights built a series of gliders. The chief defect of earlier machines had been a lack of controllability. When they pitched and tilted in gusts of wind, the pilot could control them only by shifting the weight of his body. In practice this proved inadequate. Hence the first problem of the Wrights was to devise some means of handling their gliders. In order to secure lateral controllability, they hit on the scheme of warping the wings. The rear or trailing edges of the outer part of each wing were made flexible. By means of a lever, the pilot could bend them in such a way that the edge of one wing was warped upward while that of the opposite wing was warped downward. The plane would then, of course, tilt

toward the side of the upward warped wing. By means of this device, they were enabled to maintain lateral control. These warped wings were the forerunners of present-day ailerons.

Fore-and-aft control was accomplished by means of elevators similar to modern ones except that they were placed ahead of the wings instead of behind them. They were operated by another lever. When they were tipped downward the plane tilted downward, and vice versa. Thus the problem of control in straight flight was solved.

Later on, in 1902, a rudder was added which permitted maintenance of a steady course. During this year over a thousand glider flights were made, some of them covering over 600 feet and lasting over a minute. The practicability of positively controlled gliding flight was definitely demonstrated and many scientific data on the subject accumulated.

Obviously, the next step was power-driven flight. If an engine and propeller could be installed in a glider, it could rise from level ground and sustain itself. This problem the Wright brothers attacked in 1903. They built a 25-horsepower gasoline engine of their own design and mounted it in a glider. By means of sprockets and chains, it drove two propellers, set behind the wings. The engine weighed 250 pounds, and with the pilot aboard the entire airplane had a weight of 900 pounds. This was by far the heaviest machine they had yet constructed, and consequently a launching device was required. This need was met by mounting the plane on a car which ran along a single rail. A rope attached to the car ran through pulleys to a weight at the top of a wooden tower. When released, this weight would fall and aid the propellers in pulling the plane forward.

Many difficulties were encountered in construction. At first the plane failed to leave the ground. Numerous trials

were made, resulting in various changes in design. Winter arrived without any actual success being recorded. After a period of bad weather, another trial was finally set for the 17th of December, 1903.

Morning dawned bright and cold, with a 27-mile wind blowing from the north. In any modern training school, beginning students would have been kept safely on the ground. But only in a brisk wind was this low-powered machine able to rise. The first try was Wilbur's. He climbed into the plane, started the engine and warmed it up. Then, at his signal, Orville released the weight. The plane started forward. But something went wrong, and it failed to leave the ground.

It was now Orville's turn. The plane was brought back to the head of the runway and once more prepared for flight. The engine was started and warmed up again. At Orville's signal, Wilbur released the weight. Once more the plane started forward, engine throbbing and propellers whirling. It gained speed slowly but steadily. The end of the track approached. But just before it was reached, the plane rose from the car into the air. It was flying.

Its flight was erratic. But when it is remembered that to-day the student is allowed ten hours' instruction, it is only natural that the first man to fly an airplane should have had trouble controlling it. It would shoot upward eight or ten feet, then suddenly dart for the ground. This continued for 12 seconds. Finally, on one of its downward swoops, it struck the earth and came to rest safely on its landing skids. It was 120 feet from the point where it had risen into the air. Man's first flight in an airplane was an accomplished fact.

Four other flights were made on this same day. On one of them the plane stayed in the air 59 seconds and covered

Courtesy of Aeronautical Chamber of Commerce.

Orville Wright flying an early make of plane in 1905 at Kitty Hawk, N. C.

a distance of 852 feet. These were the duration and distance records for 1903. For shortly thereafter the Wrights suspended flying for the winter and turned their attention to the designing of their next plane.

During succeeding years the Wrights made steady progress. In 1904 they made a flight of 5 minutes 17 seconds, covering more than 3 miles. They also made a circle in flight. In 1905 the record was pushed up to 24 miles in 38 minutes. But there were still many fundamental problems to be solved. Hence for every minute in the air, many hours had to be spent in design and construction work. Progress was necessarily slow. In the effort to secure needed funds, the patents were offered to both the American and British governments. But no encouragement was received. So finally the Wrights went to France.

Meanwhile flying had been commenced in Europe. In 1906 Santos-Dumont, in France, made the first power-driven heavier-than-air flight in the eastern hemisphere. But his machine was inadequately controlled, and he was able to go only a few hundred yards in a straight line. Nor did the Voisin biplanes flown in 1907 by Delagrange and Henry Farman accomplish much more than this, for in none of them were the principles of control satisfactorily worked out. Naturally the French were skeptical about aviation.

This was the situation when the Wrights arrived in France. But within a few weeks they had focussed the attention of the entire country on their machines. For, on September 21, 1908, Wilbur Wright made a flight of an hour and a half during which he performed evolutions never before seen there. Other flights followed in quick succession. And during 1909 not only were their European patents bought by a French concern, but the American government

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made a contract with them as well. From then on their success was assured. They went on steadily perfecting their designs until the airplane became a reliable machine.

But there were other pioneers whose names are likewise permanently linked with the infancy of aviation. In 1908 Glenn Curtiss, who takes precedence over all except the Wrights in the annals of American flying, was building planes in Hammondsport, New York. During this year he gained national distinction by winning the *Scientific American* trophy with a speed of 37 miles per hour. He constructed the first plane equipped with a pontoon which enabled it to rise from the water. And in 1910 he made his famous Hudson River flight, covering the 135 miles from Albany to New York in two hours and a half, at the rate of 53 miles per hour.

Meanwhile Louis Blériot of France had commenced building his famous series of monoplanes. No flights over water had yet been attempted, and a prize of £1000 had been offered by the London *Daily Mail* to the first aviator who crossed the English Channel. Blériot set out to make the flight. He built a plane, but on several trials it failed to perform satisfactorily. His resources became practically exhausted. Finally a successful flight appeared to be the only thing which would enable him to continue. On the 25th of July, 1909, his plane was wheeled out of its hangar for the crucial test.

At four-thirty in the morning Blériot took off. In the gray light of dawn he headed out over the Channel. A destroyer, guarding the flight, turned and steamed at full speed toward Dover. But the plane, flying at an altitude of 250 feet, quickly caught up with it and passed it. The morning was hazy, and in a few minutes the pilot could see nothing but sea and sky. It was an anxious time. But

Courtesy of Aeronautical Chamber of Commerce.

Blériot flying in his monoplane across the English Channel.

he pressed on northward at full speed, and presently a vague outline appeared. In a short time he was over the cliffs of Deal. Then, after circling to select a landing place, he brought his wheels down on English soil. The prize was won. But even more important, his name was given to the world, and from then on financial support was assured. His monoplanes were soon familiar sights around all aerodromes.

The status of aviation in 1910 is well illustrated by the international meet at Belmont Park, New York, in October of that year. Six makes of planes were entered, four French and two American. The Wright, Curtiss and Farman machines were biplanes, while the Blériot, Antoinette and Demoiselle were monoplanes. Of the 26 pilots entered, eight were French, three British and the rest Americans.

The monoplanes were in general plan similar to their descendants of to-day, though of much slenderer construction. The biplanes, however, had no fuselages at all. The pilot sat in a seat on the forward edge of the lower wing. Between the wings was a maze of struts and brace wires, as well as the little engine. Right behind the latter was the propeller. The tail surfaces were set on long rods trailing back from the wings. And in the Curtiss and Farman types the elevators were set on similar rods projecting out in front.

A course three miles in circumference was laid out, leading past the grandstand and circling the park. Each day contests were held in which prizes were offered for speed, distance and altitude. Pilots competed for these, and flying was carried on almost constantly during every afternoon of the meet, which lasted a week. One report of a day's events in a current magazine says that "the spectators were treated to the rare spectacle of seeing at one time ten aeroplanes in

the air—a veritable flock." Drawn by the novelty of aviation, great crowds attended the meet. Accounts of it were featured in the daily papers, and photographs of the pilots and their machines became familiar to readers.

Occasionally planes were wrecked in taking off or landing, for the grandstand and other obstructions adjacent to the field set up choppy air currents. But none of these mishaps were serious. And one afternoon there was a surprising demonstration of the airworthiness of planes. Two Wright pilots, Johnstone and Hoxsey, had taken off in their machines for an altitude contest. While they were up, the sky grew dark. Wind began to whistle, and all the other pilots dropped to the safety of their hangars. In vain the crowd scanned the sky for the two Wright planes. They had disappeared. Considerable uneasiness was felt for their safety.

But next morning the papers carried the account of their adventures. With their engines running at full speed, they had been blown steadily backward by the violence of the gale. Hoxsey had landed 25 miles away, while Johnstone had been blown a full 40 miles to leeward. Next morning they flew back to the park. And Johnstone brought with him a barograph which read 8471 feet. He had been up over a mile and a half in the storm.

The principal speed event of the meet, the Gordon Bennett Cup Race, was won by the English pilot Claude Grahame-White in a Blériot plane. Leblanc, a Frenchman, in another Blériot, finished 19 laps at a higher speed. But on the last lap his engine failed and in attempting to land the plane was wrecked. No one else approached Grahame-White's time. So the Gordon Bennett cup went to England.

But on the last day of the meet the world's altitude record, previously held by France, was recaptured for America. Johnstone in a Wright plane soared up until he was a barely

discernible speck in the sky. When he came down his barograph read 9714 feet. Thus the men who built the first successful airplane saw one of its direct descendants climb higher than any plane had ever gone before. It was a fitting conclusion to the meet.

CHAPTER II

THE DEVELOPMENT OF MODERN AVIATION

AIRPLANE construction was stabilized along its present lines by the World War. Prior to 1914, aerodynamics was an uncertain science. Individual designers followed their own inclinations, and as a result planes were widely divergent in characteristics. Almost every imaginable combination of structural features was tried out. Some machines were monoplanes and some biplanes. Some were tractors, with propellers ahead of the wings, and some were pushers, with propellers behind. Elevators projecting out ahead were still seen. Fuselages had only begun to be used. In many planes the pilot still sat in the open, stuck out in front of the wing or slung beneath it. Aircraft differed as much as the men who built them.

The first thing that the war did for aviation was to make the biplane standard. The truss construction of its wings gave it greater strength than the monoplane type. This permitted higher speeds and more rapid maneuvering. As speed and maneuverability are two of the most important characteristics of a military plane, all designers eventually concentrated on the biplane type. The most practical form was found to be that which has since become the conventional one. Accordingly the majority of craft were soon being built with enclosed, streamlined fuselages carrying the engine in the nose, the control surfaces at the tail and the crew in an open cockpit or cockpits.

The principal uses to which airplanes were put during the war were observation, combat, and bombing. At the beginning of hostilities, they were employed to fly over the enemy lines and bring back reports of troop movements. Later on, with the development of radio communication, artillery observation became possible. It was found that the fire of heavy guns could be accurately directed by means of reports from the air. Observation squadrons were organized and became part of the forces at the front.

But the presence of hostile observation aircraft led naturally to the development of planes capable of attacking them. A synchronizing device was perfected whereby a machine gun could be so mounted in a plane that it would fire through the propeller, its bullets passing between the revolving blades. The gun, fixed rigidly in the fuselage, was then aimed by diving toward the objective and pointing the entire plane at it. Competition at once began in the construction of small, fast single-seaters, carrying fixed guns of this type and capable of maneuvering at high speeds. Combat tactics were developed, and clashes between hostile patrols soon became a regular part of aerial activity over the lines.

As the war progressed larger planes, capable of carrying heavy loads, were successfully designed and built. With these, bombing operations were possible, and raids into hostile territory were made more and more frequently. During the latter part of the war, such operations were carried on regularly. Much of the bombing was done at night, when the raiders were screened by darkness from hostile fighters and anti-aircraft batteries. The night attacks of the German Gothas on the city of London furnished one of the most spectacular chapters in the aeronautical history of the period.

The magnitude of the war obscured the personalities of all pilots save a few of the most brilliant aces. But these shone out among the outstanding figures of the time. The names of Guynemer, Fonck, Bishop, Richthofen and Rickenbacker, leading aces of their respective countries, will be remembered for many years. Their exceptional skill and personal valor distinguished them in a field where these qualities were expected even of the novice. They became the heroes of their armies, and marvelous tales of their adventures were told. In them was expressed more closely than in any others the spirit of medieval knighthood, when personal hardihood, skill and courage formed the basis for legends that still come down to us. They alone, among all participants in the Great War, gained distinction in single combat.

The close of the war left aeronautics a fully developed science. Under the stimulus of military necessity, the airplane had evolved from an experiment into a practical vehicle of the air. And it was not long before men were trying out its capacities in peace-time enterprises. One of the first feats which attracted the attention of aviators was the crossing of the Atlantic. Within six months after the Armistice, three expeditions were under way with this accomplishment as their goal.

The first to attempt a direct flight were Hawker, a British pilot, and his navigator, Mackenzie-Grieve. In a Sopwith biplane they took off from Newfoundland on the evening of May 18, 1919. With good weather conditions, they headed eastward. But soon the stars were obscured, and they found themselves in clouds and rain. Throughout a stormy night they held to their course. But morning brought a greater danger. Their engine was heating up. Obviously it would only run a little longer before letting them down

into the wind-swept sea. Disregarding their course, they searched anxiously for a ship. At first the ocean was blank. But, as they were almost ready to give up hope, they sighted a steamer. With the last drops of water in the radiator boiling away, they landed in the sea ahead of it, 1050 miles from their point of departure. The vessel proved to be a

U. S. Navy photo.

A 1918 training seaplane landing.

Danish ship, without radio. Only on her arrival at the Hebrides Islands, six days later, did the world learn that the aviators who had been given up for lost were actually safe.

Meanwhile three flying boats of the American Navy had started from Newfoundland. They were the NC-1, NC-3

and NC-4, huge machines weighing ten tons and driven by four engines each. A base had been established at Trepassey Bay. After several days spent in final preparations, they took off on the evening of May 16, 1919. Following a chain of destroyers stationed at 60-mile intervals, they headed for the Azores. During the night they kept safely on their course. But in the morning, in heavy fog, they became separated. The NC-1 and NC-3 were eventually forced down at sea. The former sank after its crew had been rescued, while the latter taxied to the Azores. But the third plane, the NC-4, under command of Lieutenant-Commander Albert C. Read, covered the full distance of 1380 miles and landed safely at Horta. Ten days later the flight to Lisbon, Portugal, was made, completing the first crossing of the Atlantic by air.

But the ocean was still to be crossed in a single flight. During June, Captain John Alcock and Lieutenant Arthur Brown, English pilots with distinguished war records, set up and tested a Vickers-Vimy plane at St. Johns, Newfoundland. The machine was a large twin-motored bomber capable of carrying a heavy load of fuel. On the 14th day of June everything was in readiness for the flight and the weather was favorable. Accordingly, late in the afternoon, Alcock and Brown took off and headed out to sea. But as the sun went down, they ran into thick weather. Continuing on their course, they encountered alternately fog, rain and clear skies. Sometimes they skimmed along a few hundred feet up. At other times they rose as high as 12,000 feet. Once ice started to form on the wings, which became coated with it before warmer air was reached. Whenever the stars were visible Brown, the navigator, took sextant observations and calculated their position.

Morning found them still on their charted course and nearing the goal. Soon two small islands were seen through the mists. A few minutes later the mainland of Ireland appeared and they recognized the radio station at Clifden.

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Start of the first non-stop trans-Atlantic flight from Newfoundland, June 14, 1919, by Alcock and Brown.

They selected what appeared from the air to be a good field and made a landing. It proved, however, to be a bog, and the plane was damaged. But the pilots were fortunately unhurt. They had safely completed the first non-stop

crossing of the Atlantic, 1890 miles in 16 hours and 12 minutes.

During the years succeeding the war, commercial aviation in America got under way slowly. There were many pilots, returned to civilian life after demobilization. And the government offered for sale at a fraction of their cost many of its surplus planes. But the latter, designed primarily for military purposes, did not prove particularly well fitted for commercial use. Moreover, the public still thought of flying as a military activity. Comparatively few people felt any desire to go up themselves. While in 1921 there were 125 commercial operators, many of them had only one or two planes and none of them found any great demand for air transportation.

Air mail had been inaugurated in 1918. During the following year it was extended. And in 1920 transcontinental mail service was established. Letters were carried from coast to coast in two days, cutting in half the best time by rail.

Three years later, appropriations were made for lighting the transcontinental airway. With beacons installed, continuous flight from New York to San Francisco became possible. During a week's experimental operation in September 1923, relays of planes carried the mail across the continent in 26 hours. Not long afterward regular through service was established.

In May 1923 the first non-stop flight across the American continent was accomplished. Two army pilots, Lieutenants Macready and Kelly, took off in a Fokker monoplane from Roosevelt Field, Long Island, and headed westward. At an average speed of 100 miles an hour they crossed the Appalachians, skimmed above the plains of the Middle West and then climbed over the Rockies. The following day, 26 hours

50 minutes after taking off, they landed at San Diego, having covered a distance of 2700 miles.

The outstanding aeronautical event of the year 1924 was the round-the-world flight of two United States Army planes piloted by Lieutenant Lowell Smith and Lieutenant Erik Nelson. There were originally four of these Douglas world-cruisers, large single-engined biplanes which could be equipped with either wheels or floats. The start was made at Seattle on April 6, with the planes on floats for over-water flying. The route lay up the Canadian and Alaskan coasts to the Aleutian Islands. Despite cold, storm and fog three of them made this leg of the journey safely. One was wrecked on an Alaskan mountainside, but the crew eventually made their way safely to civilization.

The remaining planes waited at Attu, the most westerly of the Aleutian Islands, for favorable weather. On May 15th conditions appeared satisfactory, and they took off for the Komandorski Islands. They made the trip safely, landing alongside the U.S.S. *Eider*. The following day they went on to the Kurile Islands, completing the first crossing of the Pacific by air. The trip down the Asiatic coast brought them to Tokio on May 24. Thence the route led to Shanghai, Hongkong, Saigon, Bangkok and Calcutta, through heat and tropical storms which offered obstacles as difficult as the snows and winds of the Arctic.

At Calcutta floats were replaced by wheels for the journey across the continents of Asia and Europe. After short stops at Bagdad, Aleppo, Constantinople, Bucharest and Vienna, they arrived at Paris on July 14, where they were given a tumultuous reception. Thence they flew to Croyden, the famous English airport, stopping long enough to receive the hospitality of England. But they quickly pushed on to

Hull, where floats were again put on for the trip across the Atlantic.

Shortly after leaving the Orkneys, the third plane, piloted by Lieutenant Wade, was forced down at sea. It was found by an American cruiser and the crew picked up, but efforts to salvage the plane failed and it sank. Lieutenants Smith and Nelson continued on to Iceland. Here they were confronted by the longest over-water flight of the trip, the 820-mile stretch of water between Iceland and Fredericksdal, Greenland. Sixteen days were consumed waiting for favorable conditions. Finally on August 21, they took off. At first the weather was clear. But part way across, fog was encountered, which became constantly thicker. The two planes endeavored to keep together. For a time they succeeded until, as they flew low over the water, an iceberg suddenly loomed through the fog dead ahead. Forced to zoom instantly, they lost each other and had to proceed singly.

By remarkable skill in navigation, both planes kept to the course. Ploughing steadily onward through endless fog, they covered mile after mile of ice-strewn sea. At last the mountains of Greenland appeared dimly. Skirting the icy coast, they flew southward to the haven of Fredericksdal. Here the two planes landed hardly an hour apart, after the most difficult and dangerous eleven hours of the entire journey.

From then on the trip became increasingly easier. A short over-water flight brought them to Labrador. Soon they were out of the Arctic cold and flying down the Canadian coast. On September 5 they brought their planes down once more in American waters at Mere Point, Maine. Here began a triumphal journey across the United States to Seattle where on September 28, five and a half months

after they had taken off, they completed their flight around the world. During 371 hours in the air, flying at an average speed of 74 miles an hour, they had covered 27,533 miles.

In May of 1926 the possibilities of the airplane in exploration were strikingly demonstrated by the flight of Lieutenant-Commander Byrd to the North Pole and back. With a tri-motored Fokker monoplane, he established a base at Kings Bay, Spitzbergen. After many difficulties had been overcome, the plane, with Floyd Bennett at the controls and Byrd navigating, finally succeeding in getting into the air shortly after midnight on May 9, 1926. The distance to the goal was over 700 miles across the Polar sea. The cliffs of Spitzbergen soon faded from sight, and they looked down on a desolate expanse of ice fields broken only by dark lanes of water. In these high latitudes, the magnetic compass was useless. The course had to be maintained by means of a sun compass, while the position of the plane was frequently checked by sextant observations of the sun.

It was the beginning of the Arctic summer of six months' day, and the weather was fair. They flew on without difficulty for some time. But as they neared the Pole, an oil leak developed in the starboard engine. The length of time it would run was uncertain, and a crucial decision had to be made. But after consultation they determined to press on. So, at 9:04 A.M. Greenwich time, Byrd's observations showed him that he was over the Pole. They swung around several times in a five-mile circle while he checked his calculations. Then, their objective reached, they turned southward. The doubtful engine continued to run, and the leak finally ceased. At about six that afternoon they sighted Kings Bay and a few minutes later dropped to a safe landing.

The year 1927 may be considered as a turning point for

American aviation. While it had been growing steadily, the country at large had not realized its growth. Some significant demonstration of the capacity of the airplane was needed to impress on people the fact that it was no longer primarily a military machine, but a practical means of transportation as well. This demonstration was afforded by the flight of Charles A. Lindbergh from New York to Paris. On the morning of May 20, 1927, he took off alone in a single-engined Ryan monoplane. Following the North American coast, he flew to Nova Scotia in twelve hours, encountering several local storms en route. Passing over Cape Breton, he then struck out to sea. Through a night of fog and cold, whipped by recurring storms of rain and sleet, frequently buried in clouds, and flying by means of instruments alone, he held to his course.

With sunrise came clearer weather. The clouds lifted and broke, revealing the white-capped Atlantic rollers. During the morning the ocean was bare of ships. But in the afternoon Lindbergh sighted two fishing vessels, the first indication of his approach to Europe. An hour later a shore line appeared ahead. Dropping low over it, he was able to identify it as the southwestern coast of Ireland. From then on his course was clear. Above Ireland and the Irish Sea he flew, thence along the southern shore of England and over the Channel that had first been crossed by airplane less than eighteen years before. Sunset found him at the mouth of the Seine. Soon a blaze of lights appeared ahead which could mark no other place than Paris. A little after ten o'clock, in the presence of a tremendous crowd, he brought his plane to earth at the Le Bourget airport.

Lindbergh's feat seemed to be the signal which began a long series of notable flights. Both Chamberlain and Byrd followed him across the Atlantic. An army plane, piloted by

Lieutenants Maitland and Hegenberger, flew from San Francisco to Honolulu. Other flights across both the Atlantic and Pacific were made. In 1928 Captain Wilkins and Lieutenant Eielson, in a Lockheed-Vega monoplane, flew across the roof of the world from Alaska to Spitzbergen. Captain Kingsford-Smith, an Australian, with three companions, crossed the Pacific from San Francisco to Australia in three long flights. And other achievements, too numerous to mention, confirmed the country's awareness that a new age in aviation had arrived.

From the point of view of airplane construction, two developments marked the new period. These were the return of the monoplane and the air-cooled engine. Both had been prominent in the early history of aviation, but both had been superseded during the war by the biplane and the water-cooled engine. Now experiments with thick wing sections developed the fact that wings could be internally braced to provide sufficient strength. As the absence of struts and external brace wires decreased the resistance and increased the efficiency, monoplanes rapidly came into favor for transport work. At about the same time, radial engines were developed with cylinders fixed instead of revolving as were those of early rotary types. As the stream of air cooled them sufficiently, it was found possible to do away with the water-cooling system and the troubles it generated. Most of the important flights of recent years have been made with air-cooled engines.

Since Lindbergh's flight, the development of commercial flying in America has been so rapid that observers find difficulty in keeping up with it. In 1929, 150 manufacturers of aircraft were producing more than 400 different models, varying in size from small single-seater sport craft to huge air liners carrying thirty passengers. These planes were

employed for many different purposes, among them passenger, mail and express transportation, surveying and other aerial photographic work, advertising, dusting and spraying crops, seeding ground, forest patrol, sightseeing, training and private sport flying. And their use is being constantly extended. Commercial aviation has now overshadowed the military aviation from which it grew.

The spread of air lines is an accurate indication of the growth of air-consciousness in this country. The use of air mail increased steadily until the volume was sufficient to make the principal mail lines self-supporting. The government then turned the actual transportation of postal matter over to private enterprise. Contracts were awarded to responsible companies, and all principal cities now have air mail service. Lines are being extended as rapidly as traffic warrants.

The demand for passenger transportation has likewise grown steadily. The saving of time made possible by air travel is being appreciated by more and more people. Air terminals have been built at most large cities, and trimotored liners are seen leaving and entering them in rapidly increasing numbers. It is now a simple matter to go to a city ticket office, make a reservation for another city five hundred miles away, drive out to a terminal in a swift car, step into the comfortably appointed cabin of a plane and reach one's destination in five hours' time. The extension of air lines has lately become so rapid that statistics can hardly keep pace with their growth. There are now hardly any large cities which are not served by at least one.

The recently founded Transcontinental Air Transport furnishes a typical example of a carefully organized air line. Over this route passengers can go from coast to coast in 48 hours. Leaving New York in the evening on a Pullman,

they transfer the next morning to a plane for a day's flying across the Middle West. The second night is likewise spent on a train, which is left the following morning for another plane. In this, Los Angeles is reached the same evening. A year of preparation was required to build the system before the first passenger was carried. Every requirement was foreseen, and every detail fitted into place. Nothing that might add to safety and reliability of operation was neglected. The route was chosen after exhaustive analyses of distance, topography and weather conditions. The chain of airports leased or constructed along it furnishes facilities for every need, from overhauling a plane to sending a telegram for a passenger. Fields for use in case of necessity are maintained at regular intervals between terminals. Each huge tri-motored all-metal plane, built especially for the system, has a cabin insulated against cold and sound, heated by the engine exhausts, decorated in delicate lacquered colors, and equipped with upholstered chairs, adjustable windows with silk shades, individual reading lights and folding tables, baggage racks, lavatory, steward's pantry and automatic ventilating system. Eighty meteorological observers, some of them at points as much as a hundred miles away from the route, make regular reports which, together with the reports from two hundred government stations, furnish continuous weather information. Every plane is equipped with a radio set by means of which the pilot can talk to any ground station along his course. Every ten miles are beacon lights, ready to guide a plane overtaken by darkness or, later on, to form an airway for the Pullman liners which will eventually fly through the night. Each airport can be illuminated by powerful floodlights, while planes are equipped with emergency landing lights and parachute flares. And finally, pilots are selected with ex-

haustive care. No effort is spared to insure that passengers will travel with speed, safety and comfort.

Paralleling the development of air lines, equal attention is being paid to the amateur who flies for pleasure. A wide variety of planes is offered for his selection. He can have a light two-seater sport model, a comfortable cabin cruiser, a small, fast amphibian for commuting purposes, or any type of craft he desires. With greater production, prices are dropping within reach of an increasing number of people. And flying schools can be found throughout the country ready to teach a new owner to handle his machine. Under these conditions it is not difficult to visualize the time when private planes will be numbered by tens of thousands.

Aviation has unquestionably come to stay. It has established itself as a part of American life. The small plane is making a place for itself in the same field as the automobile. The large plane has become a competitor of the railway and steamship line. Flying rests on a basis of sound engineering principles. And its practicability as a means of transportation has been demonstrated for all time.

CHAPTER III

WHY AN AIRPLANE FLIES

MANY people, though they know that an airplane flies, have only a limited understanding as to why it does. Yet the principles governing its flight are comparatively simple. And familiarity with them is of the greatest help in understanding the various problems of aviation. Without such knowledge, flying must continue to be somewhat of a mystery. But brief study of them will give the insight needed for real comprehension, not only of what happens to a plane in the air, but of why it happens. So, in this chapter, the principles of heavier-than-air flight will be explained.

A plane is sustained by the lift of its wings as they move through the air. Take a piece of cardboard, or better yet a fan, and hold it at arm's length, turned slightly upward from the horizontal. Now swing it swiftly around. You will feel a definite upward force on it, which will try to raise your arm. This is the same force which holds up a kite, held stationary by a line while the wind blows past it. And it is the same force which sustains a plane. For whenever a flat surface is thus moved through the air held at a slight angle to its line of motion, its forward edge being the higher, the air exerts a force on it tending to raise it and anything to which it is attached. This force is called lift.

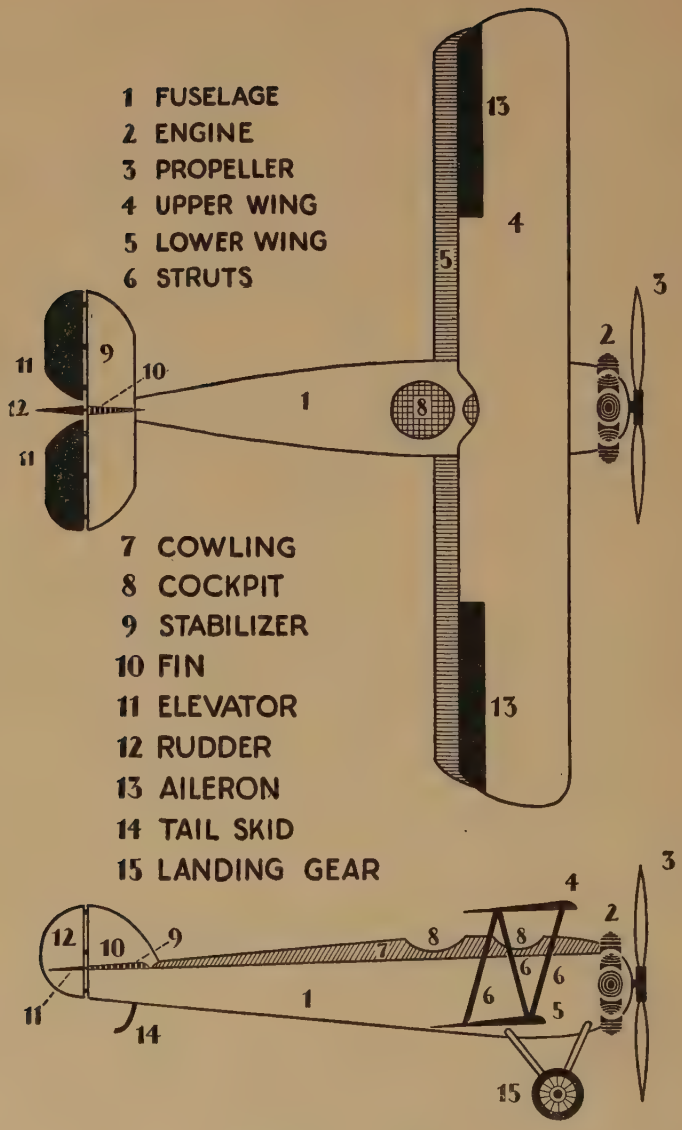
However, if you move the cardboard slowly, you will find that you feel no upward force. It must be moved swiftly before this becomes appreciable. For lift increases with

the square of the velocity. Hence a plane must keep moving rapidly to stay in the air.

An airplane may be defined as a self-propelled vehicle, heavier than air, which flies with a crew and cargo. Its essential parts are divided into five groups—fuselage, wings, engine and propeller unit, control surfaces and landing gear. The fuselage is the body of the plane. In it are carried crew and cargo. The wings, projecting from the fuselage, are lifted by the air as they move through it and thus sustain the weight of the plane. The engine and propeller maintain the speed necessary to produce the required lift. The control surfaces enable the pilot to direct his flight. And the landing gear enables the plane to take off from and land on the ground or water.

The classifications of aircraft usually made include landplanes, which are airplanes designed to fly from land, and seaplanes, which operate from water. A monoplane has one wing, a biplane two, and a triplane, a type rarely seen, three. Tractors have the propeller or propellers ahead of the wings; the pushers have theirs behind. Single-, twin-, and multi-motored planes have respectively one, two and several engines.

Any surface which is intended to be acted on by the air through which it moves is called an airfoil. But a flat surface is not an efficient airfoil, and hence an airplane wing is not flat. The lower surface curves only slightly, but the upper surface curves upward sharply from the forward or leading edge, then tapers gradually to the rear or trailing edge. This curvature is called camber. When the wing moves forward, the air which strikes the under surface exerts lift just as it would on a flat piece of cardboard. In addition, the air which hits the abruptly curving leading edge is deflected sharply upward. A low-pressure area above the



The parts of an airplane.

upper surface of the wing results. This partial vacuum aids materially in lifting the wing, its effect being, in fact, larger than the direct lift on the under surface. The gradually tapering rear part of the wing conforms to the natural stream of the air. This permits the latter to flow past smoothly, without any large eddies which would otherwise exert a retarding force.

The lift of a wing varies with its area, the density of the air, the square of the velocity and the angle of attack. Obviously, the larger the area of a wing, the greater will be its lift. This force is greatest at sea level, decreasing steadily as the plane rises on account of the lessening density of the air. Any increase in velocity causes a large increase in lift. At 70 miles an hour, other things being equal, it is approximately twice as great as at 50 miles an hour. Finally, the angle of attack affects the lift. This is the angle between the chord of the wing, the line connecting its leading and trailing edges, and its line of motion through the air. At a zero angle of attack, the lift is inappreciable. But as the leading edge is raised, it increases proportionally. This increase continues until an angle of approximately 15 degrees is reached. If the leading edge is then further raised, the lift decreases abruptly to zero. The angle at which this change begins is called the stalling angle, and the condition is called a stall.

But the upward force of lift is not the only one affecting the wing. The resistance of the air to its forward motion must also be taken into account. This force is called drag. It likewise varies with the angle of attack, rising as the latter is increased. A wing is set on a plane at the angle which produces the highest ratio of lift to drag. This angle is usually between two and four degrees. The ratio determines the wing efficiency. That is, if the lift of a wing is 2500 pounds

and its drag is 250 pounds, the wing efficiency is 10. Wings are designed with various different forms of camber, all aimed to give the greatest wing efficiency for the particular types of planes on which they are to be used.

The air resists the motion of all other parts of an airplane as well as that of the wings. This force is called parasite resistance, and includes the friction caused by the fuselage, struts, brace wires, landing gear and other parts. It can be greatly cut down if all parts are designed with streamline forms, rounded in front and tapering to an edge behind. The wing drag plus the parasite resistance together composes the total resistance of a plane.

The propeller blades are, in effect, small inclined surfaces which move rapidly through the air as the propeller rotates. Their movement produces forces corresponding to the lift and drag of a wing. The principal force is a forward pull, called thrust, and produced in the same manner as lift. This is the force which pulls the plane through the air. The latter's resistance to the movement of the blades produces a force similar to drag, which is called torque. It tends to rotate the plane and would cause it to tip sidewise if it were not offset by an adjustment of the angles of wing setting to prevent this. The pitch of a propeller is the distance which it would advance in making one complete revolution in a solid medium. In actual practice, however, the air slips backward, and the plane moves forward only about three-quarters of this distance.

It is thus seen that four forces act on a plane in flight, and that each pair must be in balance. The weight of the plane, acting downward, must be balanced by the lift, acting upward. The resistance, tending to retard its movement, must be offset by the thrust, which draws it forward. All flight is governed by these forces.

The speed of a plane through the air must be sufficient to produce lift equal to the weight before it can leave the ground. Hence it must run along the surface and gain this speed before it can rise into the air. In the average training plane a rate of forty miles an hour is sufficient. Once in the air, it must keep moving ahead at this rate or above it in order to stay up. If the speed drops below the critical point, the plane is said to stall. The critical rate is known as the stalling speed. A stalled plane must descend, and as it drops, the angle of attack of its wings will become large, further decreasing the lift. If held in a stall, it would keep dropping until it hit the ground. But as soon as forward

Positions of a plane in flight.

speed is picked up once more, lift will be regained. A plane which is moving faster than the stalling rate is said to have flying speed.

If the engine is run at maximum speed, thrust will pull the plane ahead at an increasing rate. But this will increase the resistance, which also rises as the square of the velocity. Finally the resistance will exactly equal the thrust. The plane will then be traveling at its maximum speed. Thus it is seen that, in level flight, a plane is restricted between two limits of speed, a minimum limit determined by lift and weight and a maximum limit determined by thrust and resistance.

In order to climb, the nose of a plane is raised. The plane then, in effect, goes up hill. The steepness of the incline

up which it can go depends on its power. If the effort is made to climb too steeply, it will slow down, just as an automobile slows down on a steep hill. A stall will then result. In the average training plane, eight to ten degrees is a normal climbing angle.

In order to come down, the engine is throttled down. The plane is then tilted down into a glide so that the pull of gravity takes the place of thrust in keeping up its forward speed. In effect, it coasts down hill. The angle must at all times be steep enough to maintain sufficient speed. If the glide is flattened too much, the plane will slow down and stall.

A stalled plane is not under full control. But control can always be regained by tilting the nose downward into a steep glide. Under the pull of gravity, it will at once pick up flying speed again. No properly designed plane can fall so long as flying speed is maintained. The air supports it as surely as the sea supports a ship.

In order to utilize the lift of its wings, an airplane must be under the control of its pilot. Otherwise it would be impossible to make any sustained flight. But a wing alone moving through the air is unstable and cannot be controlled. Hence auxiliary airfoils are required in order to make the airplane a practicable vehicle.

Stability and control must be considered in relation to three axes. The nose of the plane may pitch upward or downward. It may swerve to right or left. Or the plane may tilt sidewise to right or left. Provision must therefore be made for meeting and controlling its movements in these three planes of reference.

In the first place, a plane must be reasonably stable. Constant, violent pitchings, swervings and tiltings, even though

they could be controlled, would make flight too difficult to be continued long. Therefore the plane must be so designed that it has reasonable stability in the air. Longitudinal or fore-and-aft stability is secured by means of the stabilizer. This is a small airfoil, roughly similar in construction to a wing, set on the tail of the fuselage approximately parallel to the fore-and-aft line of the plane. So long as the latter is flying straight ahead, either in level flight, a climb or a glide, no force is acting on the stabilizer. But if the nose pitches upward, throwing the tail downward, the stabilizer will be thrust down at an angle into the air flow. The latter will then strike its under surface and tend to raise it. Being so far back of the center of gravity, this force will be effective and will raise the tail, returning the plane to normal flight. In case the nose pitches downward, the opposite effect will result. The air flow, hitting the upper surface of the stabilizer, will force the tail down and again return the plane to normal flight.

Directional stability, or stability on a straight course, is secured by means of the fin. This is a small airfoil set vertically on the tail of the fuselage in the line of flight. In case the nose swerves to the right, throwing the tail to the left, the air flow will then strike the left side of the fin. This will throw the tail back again and return the plane to straight flight. A similar effect will occur if the nose swerves to the left.

Lateral or sidewise stability is usually secured by means of a dihedral angle of the wings. Instead of being perfectly horizontal, the wings are set on the fuselage at a slight angle up from the horizontal, not over three degrees ordinarily. In case the plane tilts to the right, it will tend to start sliding or slipping toward that side. But the right wing will then meet the relative air flow at a greater angle of

attack than the left wing. This will raise it and return the plane to normal flight.

Control of a plane is provided through three sets of control surfaces, small hinged airfoils which can be moved by the pilot. These are the elevators, rudder and ailerons. The leading edges of the elevators are hinged to the trailing edge of the stabilizer. If now the elevators are tilted upward, the air flow will strike their upper surfaces. This will force the tail down and raise the nose. If, on the other hand, the elevators are tilted downward, the tail will be raised and the nose depressed.

Directional control is secured by means of the rudder, which is hinged to the trailing edge of the fin and the fuselage. It acts in the same manner as the rudder of a boat. When it is turned to the right, the nose will swerve to the right, and vice versa.

Lateral control is afforded by the ailerons, airfoils hinged to the outer parts of the trailing edges of the wings. They are so connected that the aileron on one side is tilted downward while that on the other side is tilted upward. Thus, if they are moved so that the air flow strikes the upper surface of the right aileron and the lower surface of the left aileron, this will depress the right wing and raise the left wing. As a result the plane will tilt to the right.

It is to be noted that the plane cannot be turned by means of the rudder alone. If the attempt is made to do this, the nose will swerve and the plane may seem to be turning. But in actual fact centrifugal force will be carrying it straight ahead. In order to make a turn, the plane must be banked or tilted sidewise just as a motorcycle rider leans inward in rounding a corner. This tilts the lift of the wings sufficiently to offset centrifugal force. Hence ailerons and rudder must always be used together in making a turn.

The control surfaces are moved by means of a stick and rudder bar in the pilot's cockpit. The stick is pivoted at its base and the rudder bar at its center. If the stick is pushed forward, the elevators are depressed, raising the tail and tilting the nose downward into a glide. If it is pulled back, the nose is raised to a climbing angle. If the stick is moved to the right, the right aileron is raised and the left depressed, tilting the plane to the right. If it is moved to the left, the plane is tilted to the left. If the right side of the rudder bar is pushed forward with the right foot, the nose is swerved to the right and vice versa.

A wheel mounted on a column or yoke is sometimes used instead of a stick. Rotation of the wheel to the right tilts the plane to the right, while turning it to the left has the opposite effect. Forward and backward movement of the entire assembly operates the elevators. These are known as Deperdussin controls, and are usually used in large planes on account of the greater leverage afforded by the wheel in moving the ailerons. Two pedals hinged at the top may also be substituted for the rudder bar.

CHAPTER IV

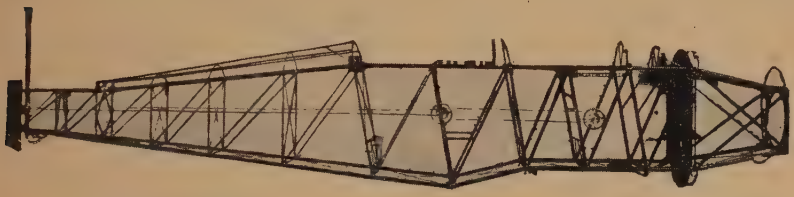
MODERN AIRPLANE AND ENGINE CONSTRUCTION

Two basic essentials establish the fundamental requirements of aircraft construction. They are lightness and strength. An airplane must be light or else it will not fly. But weight cannot be saved by the sacrifice of strength or it will fail in the air. Therefore its structure must combine these two necessary qualities. The factor of safety of every part, the ratio of its breaking strain to the maximum stress it will normally have to meet, must always be high enough to insure that no failure will occur. Success is achieved by building a plane which, on the one hand, is as light as possible and therefore capable of carrying the heaviest loads or maneuvering most rapidly, but which, on the other hand, has a factor of safety that meets the demands of sound principles of design. Every airplane represents a compromise between lightness and strength.

The materials used in airplane construction are wood, metal and fabric. Sitka or western spruce is the most generally used wood on account of its lightness, strength, stiffness and toughness, though other woods are sometimes used for particular purposes. The specifications for wood are very exacting, and only the best quality of lumber can meet the requirements. It must be straight-grained, free from large knots, breaks in the grain, pitch pockets or dry rot, and kiln-dried under properly regulated conditions. All wood for use in airplanes must therefore be carefully inspected.

Wood is, however, being used less and less for aeronautical purposes. With the development of lightweight alloys, it has been largely superseded by metal. Where formerly fittings were the only metallic parts of an airplane, main structural members are now usually built of steel or aluminum. Steel-tube fuselages are common, as are those made of duralumin. Wing frameworks are also constructed of these materials.

The coverings of wings and fuselages are made ordinarily of fabric. Linen was formerly the most used material. But in America a high grade of long-staple cotton has been found as satisfactory and much cheaper. After being stretched



Metal fuselage construction.

over the framework of a wing or fuselage and stitched, the fabric is treated with several coats of "dope," a cellulose solution. This gives it a glaze which makes it weatherproof. It also shrinks and strengthens it, so that it is drawn taut and firm over the framework.

Thin sheets of duralumin have been used with success in place of fabric. For such purposes they are ordinarily made in corrugated form to increase their strength. By using them it is possible to build an airplane entirely of metal, and a number of large manufacturers are specializing on this type of construction.

The fuselage of an airplane is a framework whose main members are four longerons. These run the entire length

of the framework and determine its general shape. They are held rigidly in place by upright, transverse and diagonal braces. The entire structure then forms a trusswork possessed of strength adequate to meet all the stresses of flight. At the forward end is the mount for the engine: a ring in the case of a radial engine, or two longitudinal bars called engine bearers in the case of engines with cylinders in vee or line. Directly behind the engine is a metal fire wall which cuts it off from the rest of the plane. Since this type of fuselage construction produces a main framework generally rectangular in shape and tapering to an edge at the rear, falsework or fairing, either of wood or light metal strips, is usually added to streamline the plane. After the fabric has been stretched over this, the fuselage has a rounded form offering the least resistance to the air. Metal cowling is placed around the engine and streamlined integrally with the fuselage, thus further reducing wind resistance.

The internal bracing of the fuselage is designed to leave clear the space required for the cockpits or cabin. The seats for crew and passengers are then installed here. There is also ordinarily a space where, on assembly of the plane, the gasoline tank is installed. Tanks are sometimes carried in the wings, however.

The wing of an airplane is built of spars, ribs and fabric. The two spars are the main transverse members. They run the entire length of the wing, and to them all ribs are attached. These ribs are the fore-and-aft members, running from the leading edge to the trailing edge and giving the wing its contour. The fabric is stretched over the ribs and transmits to them the lift received from the air. They in turn lift the spars, which are attached to the fuselage and thus sustain the weight of the plane.

In a biplane the upper and lower wings are connected by struts and diagonal brace wires. The conventional type has, between the outer parts of the wings, forward and rear interplane struts running between the forward and rear wing spars respectively. The lower wing is attached directly to the lower longerons of the fuselage, while short diagonal struts connect the upper wing to the upper longerons. Struts are now usually made of streamlined metal tubing. Diagonal wires, both transverse and fore-and-aft, form a trusswork with the struts. The wires which run diagonally outward and upward from the inner end of the lower wing are called lift wires, because they participate in transmitting the lift of the wings to the fuselage. The opposite wires, running outward and downward from the upper wing, are called landing wires, because they take the weight of the wings when the plane is on the ground.

The span of an airplane is the distance across the wings from one wing tip to the other. The chord of a wing is its fore-and-aft length, which is usually from 1/8 to 1/6 of the span. The gap is the vertical distance between the upper and lower wings. Overhang is the amount by which the upper wing projects out laterally over the lower, if at all. Stagger is the horizontal distance by which the upper wing projects out forward over the lower wing, that is, the amount by which its leading edge is in advance of that of the lower wing.

The construction of the control surfaces—elevators, rudder, ailerons, stabilizer and fin—is similar to that of the wings. Fabric is stretched over light frameworks of the required shape, braced internally by transverse members. The fin and rudder are fixed rigidly on the fuselage by metal fittings. Hinges are attached to the leading edges of the movable surfaces, while horns project from them to which

are attached the control cables. They are then mounted in such a way that they are free to move as much as necessary.

The landing gear of an airplane is carried beneath its fuselage. In the case of a single-engined plane, struts attached to the lower longerons project downward. If a landplane, these struts lead to an axle, at each end of which is a wheel of the wire-spoke type with a pneumatic tire. Some method of cushioning the impact of landing is always provided. Formerly the standard type of shock absorber consisted of coils of heavy elastic cord. The axle was set in the struts in such a way that it gained some vertical play by stretching the cords, which then eased the shock of hitting the ground. A more modern and effective method is furnished by the use of hydraulic landing gear. A piston moves in a cylinder built into the strut. This cylinder contains a heavy liquid which, on landing, permits slow movement of the piston but prevents any rapid movement and thereby eases the impact. A heavy spring is also a part of the mechanism. In some of the most modern designs, brakes are likewise included.

In the case of a seaplane, a float is substituted for the axle and wheels. This is a long, narrow structure in the shape of a pontoon, rounded at its bow and stern and flat-bottomed. It is completely covered over and water-tight. Its interior is divided by bulkheads into water-tight compartments, ordinarily eight in number, four on each side separated by a longitudinal partition.

Propellers were formerly made of laminated wood, thin strips glued and pressed together and shaped to the proper dimensions. Steel hubs were inserted at the center, while the tips were protected by thin brass sheathing. To-day most propellers are built of steel alloys, as this type is found more durable. Propellers must balance perfectly before they

can be used. Consequently they are always tested for balance prior to installation.

Every airplane must be protected against deterioration. When the strength of parts is calculated so accurately, the slightest rotting or corrosion will reduce the factor of safety appreciably. Consequently all members must be prepared to withstand the effects of exposure to weather. The principal dangers arise from dampness, which causes swelling and deterioration of wood and oxidation of metal. In the case of the former, varnish is used as a protective coating. If of good quality and carefully applied, it is impervious to moisture and will preserve the wood. Small metal parts are plated to protect them. But plated metal cannot be welded. Hence large welded steel structures such as the fuselage are carefully cleaned and then varnished or enameled. The insides of steel tubes are filled with hot, heavy oil, the ends sealed, the oil then drained out through small holes and the holes finally soldered up. Duralumin does not corrode when kept dry, but in damp salt air it must be protected by a coating of varnish and all joints should be liberally covered with grease. Regular inspection is an essential part of the maintenance of aircraft, as deterioration must be detected promptly and checked. And at intervals of a year or so, depending on the type of construction and the climate, complete disassembly and overhaul are necessary.

An airplane is propelled by an engine similar in operating principles to an automobile engine. As in the latter, gasoline is mixed with air in the carburetor, drawn into the cylinders, compressed and exploded. The force of these recurring explosions strikes the pistons in turn. The connecting rods transmit these impulses to the crankshaft, on the end of which is mounted the propeller hub. The revolution of the

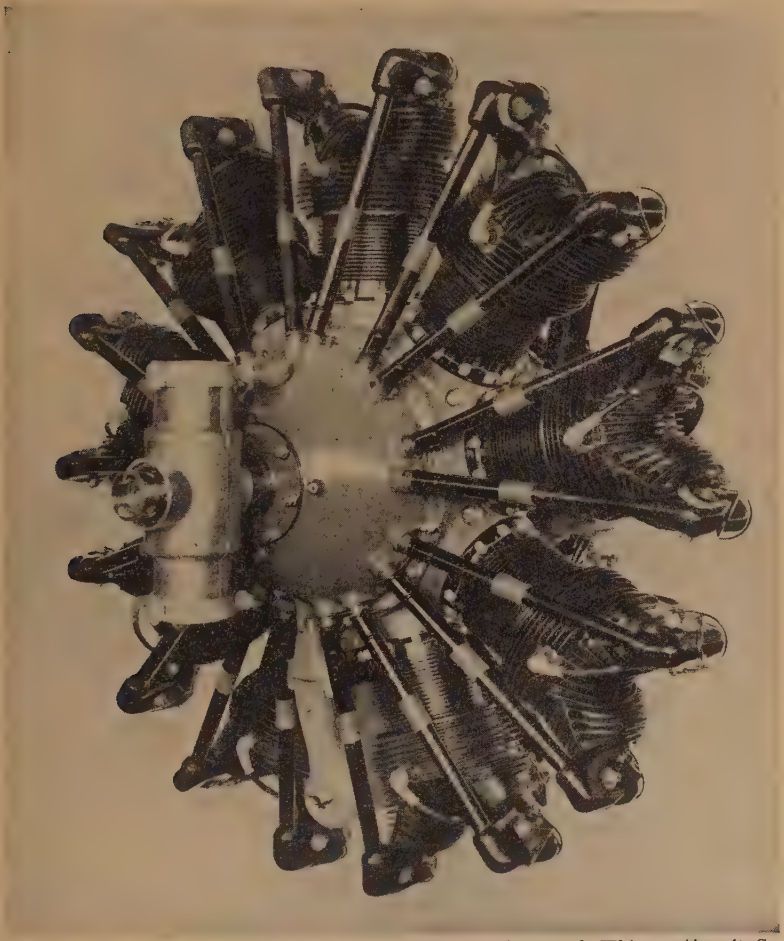
crankshaft thus revolves the propeller, and the thrust of its blades pulls the plane through the air.

Like all other members of an airplane, the engine must be light. Careful saving of weight is therefore essential. All parts must be designed so that they have the necessary strength but no more. Light alloys are used extensively in such parts as the crankcase. The majority of engines weigh from two to three pounds per horsepower.

All airplane engines operate on the standard principle of the four-stroke cycle. That is, one stroke out of each four is a power stroke. The first or intake stroke of the piston, a down stroke in a cylinder which is upright, draws in through the intake valve a charge of mixed gasoline vapor and air from the carburetor. When the piston starts up on the second or compression stroke, the intake valve is closed and the charge is compressed. As the piston nears the top of its travel, the charge is ignited by a spark in the spark plug. It explodes, and the pressure generated drives the piston down again on the third or power stroke. When the bottom of this stroke is reached, the exhaust valve opens and the piston, coming up on the fourth or exhaust stroke, drives the burned gases out of the cylinder. The cycle is then repeated.

There are two standard types of airplane engines now in use, the radial type and the line or vee type. In the former the cylinders are set in a circle around the crankcase, projecting from it as the spokes of a wheel project from a hub. They are fixed rigidly, the rotary engine in which the cylinders revolved being now obsolete. In the other type, the cylinders are set in a straight line one behind the other, or in two straight lines set in the form of a letter V. About 75 per cent of the engines now manufactured are of radial design.

Engines are also classed as air-cooled or water-cooled. In the former type, the cylinders are covered with fins, thin metal rings encircling the outer walls. These fins increase



Courtesy of Pratt & Whitney Aircraft Co.

AN AIR-COOLED RADIAL ENGINE.
Pratt & Whitney 425 H.P. 9-cylinder Wasp engine.

the surfaces of the cylinders sufficiently so that the flow of air keeps them cool. In a water-cooled engine, the cylinders are surrounded by water jackets. As in an automobile engine, water is forced through these jackets by a pump and absorbs the heat of the explosions. It is then led to a radiator, in which it is cooled by the air flow, and is returned to the cylinders. All radial engines are air-cooled, as are some line and vee type engines. They comprise in all 85 per cent of aviation motors.

Both air-cooled and water-cooled engines have all the accessory systems essential for the operation of a gasoline motor. Unless fuel flows to the carburetor by gravity, some kind of positive feed is necessary. This may be accomplished by means of a gear-driven fuel pump, which forces the gasoline through the feed pipe. Or it may be done by an air pump which keeps pressure on the gasoline tank and thus insures continuous feed. In the carburetor is an air inlet which takes in the necessary amount of air to mix with the gasoline that enters through the nozzle. The resulting mixture is an explosive vapor, whose flow is regulated by the throttle valve. By the operation of this valve the speed of the engine is controlled. After passing it, the mixture is led through the intake manifold, a branched pipe, to the intake valves in the cylinders.

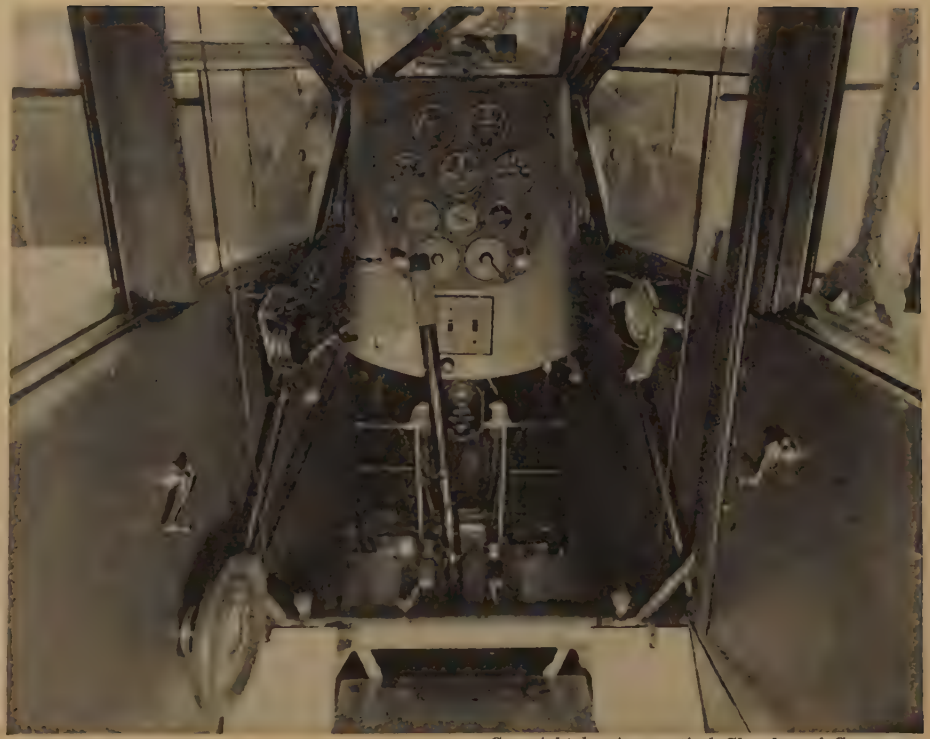
The ignition system consists of a magneto, an interrupter or breaker, low and high tension coils, a distributor, spark plugs and the necessary wiring. The magneto, driven by gearing from the engine, generates an electric current which is stepped up to a high voltage by the breaker and coils. The distributor sends this high tension current into each spark plug at the proper instant in relation to the four-stroke cycle. A spark jumps the gap between the points of the plug and fires the charge.

Lubrication is provided by the force feed system. A pump driven from the crankshaft forces oil to the various bearings. After passing through the crankshaft to the main and crankpin bearings, it is thrown out as spray on to the cylinder walls. It then falls into the bottom of the crankcase, from which it returns to the pump, either directly in the case of a wet-sump system, or through an external tank in the case of a dry sump.

Starters are ordinarily included as accessory equipment with modern engines. A frequently used type is the inertia or momentum starter. A small, heavy flywheel is rotated by means of a hand crank. When it has attained high speed, a clutch is thrown in connecting it with the crankshaft. It will turn the shaft through three or four complete revolutions, more than enough to start the engine if everything is properly adjusted.

Various instruments indicate the condition of the engine when it is running. A tachometer registers the number of revolutions per minute, the maximum being from 1600 to 2000 in the majority of engines. Gauges show the pressure and temperature of the oil. The normal operating pressure is 75 pounds per square inch. Another gauge gives the fuel pressure, which should be between 3 and 6 pounds. An adjustment on the carburetor permits regulation of the gasoline mixture when flying at higher altitudes, where it must be leaner.

Besides lightness, there are various other requirements which an aviation engine must meet. Among these are compactness, flexibility, freedom from vibration, low fuel consumption and ease of maintenance. Compactness is essential to keep head resistance as low as possible. Flexibility, or ability to run smoothly at various speeds, is important, since maneuvers in the air require frequent changes



Copyright by Aeronautical Chamber of Commerce.

An instrument board, stick control and rudder bars.

of speed. Excessive vibration would cause undue deterioration of the structure of the plane. Hence, as an engine must run at high speed during most of the time it is in the air, vibration must be reduced to a minimum. Low fuel consumption decreases the amount of gasoline required and increases correspondingly the useful load which can be carried. And finally, all parts of the engine which require frequent attention must be readily accessible.

Engines vary widely in size and power. One weighs 58 pounds and develops 20 horsepower. Another weighs 1210 pounds and develops 800 horsepower. Between these two extremes are many different types. In radial engines the number of cylinders varies from three to twelve, seven and nine being the most usual numbers. In line and vee types the number runs from four to twelve. In 1929, an analysis of the engines produced showed the following distribution by horsepower classes:

Under 85 H.P.	11
85 to 115 H.P.	12
115 to 175 H.P.	23
175 to 250 H.P.	7
200 to 500 H.P.	8
over 500 H.P.	6

To examine more closely a representative engine, a Wasp may be selected. This is a nine-cylinder, air-cooled radial engine rated at 420 H.P. at 2000 r.p.m. The cylinders, of 5¾ inch bore and 5¾ inch stroke, have steel barrels on which are screwed and shrunk cast aluminum cylinder heads. Both barrels and heads are covered with integral cooling fins. Each cylinder head contains one inlet valve and one exhaust valve, which seat on bronze inserts. The nine cylinders are bolted to the crankcase of forged aluminum.

In each cylinder is a piston of aluminum alloy, with four cast-iron piston rings. The piston in the top or number one cylinder carries the master connecting rod. Eight I-section link or articulated rods, one from each of the other eight pistons, are connected to the master rod. The single throw, alloy steel crankshaft fits into the master rod, by which it is driven during operation. The shaft rests on two roller bearings in the crankcase. Its forward end carries the propeller hub.

The intake and exhaust valves are operated by rocker arms contained in enclosed housings. These arms are actuated by tappets and push rods, which are in turn operated by cams on a sleeve on the crankshaft. These cams are adjustable to permit timing of the engine.

Gasoline is fed to a double carburetor by a fuel pump. From the carburetor the mixture is delivered to the cylinders by a centrifugal supercharger which forces it through the manifolds. The ignition system includes two magnetos, each of which fires a spark plug in every cylinder. This dual system, providing two separately fired plugs in each cylinder, reduces greatly the possibility of ignition trouble in the air. An oil pump furnishes oil under pressure to all the principal bearings. The oil, emerging into the cylinders as spray, lubricates their walls. It then drops into the crankcase, from which a scavenger pump drives it to an external tank to be used over again. A momentum starter is included as standard equipment to start the engine.

The care of his engine before, during and after flight is an important part of a pilot's duties. The life of a motor depends to a great extent on the way it is handled. A careful pilot can do much to insure its continued satisfactory operation, and can thereby definitely reduce the possibility of a forced landing.

After an engine has been started, it must always be warmed up gradually. This is necessary in order that the oil may be heated and flow freely before it is run at high speed. The speed should never exceed 1000 r.p.m. until sufficient lubrication is being provided. Opening the throttle wide prior to this time would cause appreciable damage.

When it is warm enough, the engine must be given a ground test. This is done by opening the throttle fully for fifteen or twenty seconds. All the instrument readings are observed, as is the operation of the engine. The two magnetos are tested out separately. With the throttle fully closed, the engine should not run faster than 500 r.p.m., but should not idle low enough so that there is any danger of its stopping. Any unsatisfactory reading, or any unusual sound or vibration, must be investigated and corrected before flight.

In the air, the instruments must be watched carefully. It is essential that the first indication of trouble be observed. Falling oil pressure or rising temperature may foretell a forced landing. And operation of an engine under these conditions, if continued for any length of time, may ruin it.

The engine is seldom run at full speed during flight. In taking off, the throttle is opened wide. But as soon as some altitude has been gained, the motor should be throttled down. The revolutions at a good cruising speed are some nine-tenths of those at full speed. That is, if the maximum speed of an engine is 1800 r.p.m., it should be throttled down to about 1600 r.p.m. for normal cruising.

The throttle should never be kept fully closed during a glide. It is well to keep the engine running at 1000 r.p.m. or more until close to the ground. This keeps it from cooling too rapidly, and prevents fouled plugs and warped valves. If the throttle is fully closed, it should be opened

again momentarily every five seconds or so. This is called blimping the motor.

After flight, the engine should not be stopped immediately. Instead it is allowed to idle for a few minutes in order to cool down gradually. This is sometimes accomplished by cutting off the fuel supply, then letting the engine use up the gas in the carburetor.

CHAPTER V

THE QUALIFICATIONS OF A PILOT

The day is past when either genius or exceptional courage is needed to fly an airplane. The modern transport pilot is an average man who has taken up aviation as a profession. He goes to work in the morning just the same as anyone else, looking forward neither to thrills nor to danger. He is, of course, aware that there are certain hazards in aviation, just as there are in mining or in bridge-building or in tunneling a river. But he knows what these risks are, and what safety precautions are essential to avoid them. The thought of accident is in his mind no more than in any other man's. Nor does he anticipate any particular excitement. Flying an airplane is, for him, simply his day's work.

But, on the other hand, the statement made in 1918 that "any damn fool can fly" certainly is far from the truth. To be sure, a good many of them tried it. And some of them apparently got along quite well for a while. But not many continued it permanently. Gravity had a way of terminating their flying careers. It takes more than nerve to make a competent pilot.

It will be worth while to see just what qualifications a man must have in order to become a reasonably good aviator. These are the qualifications which a transport pilot must have in order to carry out his duties in charge of an air liner. And, since gravity is strictly impartial, the private pilot must be judged by the same standards.

He need not know so much about so many types of planes as a transport pilot. But in the plane he is flying, he must be able to do anything that circumstances may require of him.

As a preliminary qualification, sound physical condition is essential. Flying requires good health and full possession of all the faculties. Eyes and heart must be examined with particular care. Medical requirements for pilots' licenses have been established by the Aeronautics Branch of the Department of Commerce. Examination by a physician familiar with them is imperative before flying is even seriously considered. A man cannot afford to take a chance on himself in the air.

The need for keeping in good physical condition may well be mentioned here. Particularly in learning to fly, steady nerves are essential. Any physical ailment will show in a student's work. And any overindulgence in late hours, particularly if they be spent not wisely but too well, is going to be expensive in terms of wasted instruction.

A word also about age. Eighteen years is the minimum at which flying is safe. And twenty is likely to bring a cooler head and steadier nerves. From there up to thirty, age need not be considered. Above the latter point, fitness for aviation is more likely to depend on the individual. Older men do not respond to the demands of flying with the same promptness. They are a little slower and less adaptable. Of course there are many exceptions. But above thirty a man should make sure that he is fitted for flying before he tries it alone.

Mental qualification for aviation, though it cannot be expressed with the precision of a report on physical condition, can nevertheless be gauged with a high degree of accuracy. The most important factor in it is a certain basic

natural aptitude for flying. Just as some inherent talent is needed to drive a car well, so this instinctive aptitude is needed to fly a plane skillfully. A man must have it born in him if he is to be a good pilot. He must take to flying naturally.

It will be of value to try to analyze this natural aptitude

U. S. Navy photo.

A Naval Training Plane.
Consolidated NY-1 with 220 H.P. Wright Whirlwind engine.

briefly. Its basic element seems to be instinctive sensitiveness to the motion of the plane through the air. Because the atmosphere is invisible, we do not realize that it is in fact a turbulent stream. Yet, whenever the wind is blowing, the irregularities of the ground—hills, valleys, trees, houses—affect it as obstacles in a creek bed do the flow of water. Everywhere waves, cross-currents and eddies are

set up. These are felt as gusts. And they may extend up to an altitude of several thousand feet. Even on calm days, the unequal heating of the ground gives rise to convection currents. Consequently the air is in reality a ceaselessly churning sea. And it is through this restless medium that a plane must fly.

Naturally the plane is affected by the gusts which it is constantly striking. Each one tries to throw it off its course. Except in storms, or under unusual conditions, no single gust is at all violent. But if the effect of each one were not met promptly, the plane would waver aimlessly around the sky. Hence constant movements of all three controls are required in order to hold a steady course.

A pilot of course knows what control movement to make in order to correct each movement of the plane. If the nose rises, he pushes the stick forward. If the plane tilts to the right, he moves it to the left. But imagine the situation if he had to think about it each time. Imagine the task if he had to make a conscious effort to move the controls every time the plane pitched or tilted or yawed. "The nose is rising, so I must push the stick forward," he might decide. But by the time the impulse had reached his arm, the plane might have tilted to the left and he would be three seconds behindhand in using the ailerons. Then while he was trying to straighten the wings up, the nose might swerve to the right. Flying would be a frantic effort to keep up with little pitchings and rollings and swervings following each other forty times a minute. In two minutes the most alert brain would be numb with fatigue.

But the problem is solved when the actual operation of the controls is turned over to the effortless processes of instinct. Take for example the control movement when the

nose rises. The first time this occurs the student must stop and think what to do. By a conscious effort of will he pushes the stick forward and returns the nose to level. But this makes a definite impression on his mind. The next time it occurs, slightly less mental effort is required and he responds a little more quickly. Each time he repeats the maneuver, the proper response comes more instinctively. Thus slowly, a little at a time, a connection is built up between eye and muscle. The sight of the rising nose now initiates an impulse which travels to his arm and produces the correct movement more and more automatically. As this connection is strengthened by repetition, he thinks about it less and less. Presently he reaches the stage where he is no longer actively conscious of willing his arm to move. When he wants to depress the nose, his muscles respond instinctively.

There are only the six basic movements of the controls, forward and back and right and left on the stick, and right and left on the rudder bar. But the combinations of these which may be required are endless. Landing, for instance, involves a complicated series of movements. As the plane nears the ground, accurate handling of the elevators demands constant use of the stick. It is repeatedly moved forward and back. At the same time a straight course must be maintained with the rudder and ailerons. Moreover, the relative amount and timing of these movements vary on every landing. And all the time it is necessary to watch the ground in order to come down in the right place.

Landings are typical of all maneuvers. Hence the basic problem in learning to fly is to develop instinctive coördination between brain and muscle. There is no time to figure a thing out. It cannot be calculated like a problem

in mathematics. The plane must keep moving or fall. Therefore the right series of movements must be made with automatic precision. In no other way can a plane be safely flown.

A comparison can be seen in the handling of a car in traffic. The novice who tried to shift gears while turning

Courtesy of Stearman Aircraft Co.

A Sport Biplane in the Clouds.
Stearman C-3B three-place sport biplane with 220 H.P. Whirlwind engine.

a corner would be as likely to step on the accelerator as on the clutch. But later on, after he has gained some experience, he can handle the gear shift with instinctive precision. His hands and feet make the necessary movements automatically while he is watching the car ahead.

The handling of an airplane is of course much more complicated. But a like degree of precision is required.

A competent pilot can hold his plane in a steep turn with ease while he is absorbed in examining a field below. He flies as he walks, conscious, not of each individual muscular contraction, but of the movement of the entire plane as a unit. This ability is what pilots call the "feel of the air."

So we now arrive at an idea of what is meant by natural or instinctive aptitude. It is ability to develop the feel of the air. This is of course never found already grown. Instruction and practice are needed to bring it out. And sometimes it is slow to appear. A student may struggle along for hours before he acquires it. But he must develop it before he can become a safe pilot. It is the most fundamental requirement in flying.

Not all men possess this instinctive aptitude. A certain proportion of students are found in whom it is lacking. They seem to be unable to develop any reliable coördination between eye and muscle. As a consequence their control movements are uncertain. In turns they slip and slide around unsteadily. Their landings are erratic, some passable, some dangerous. They have no sensitiveness for flying speed. At any moment a stall may creep up on them unfelt. Obviously a student of this kind cannot fly safely.

It must be understood that this does not indicate any lack of intelligence. Some exceptionally able men have no aptitude for flying, although they may be technical experts in other lines. They do not take to it, as they might fail to take to any other outdoor activity. Their lack is no reflection on their intelligence. They simply were not cut out to be aviators.

In the days before rigid standards were set up in service schools, a newly qualified pilot reported to a squadron. He had a reputation as an expert mathematician, and was

conceded to be brainy. But inside of a month the squadron knew that he was not cut out to be an aviator. His feel of the air showed some alarming lapses.

One day, in the course of routine operations, an officer who was an expert pilot was detailed to go up as observer in this man's plane. By some chance, he had never heard of the new man's reputation. The controls in the observer's cockpit had been disconnected. And, being in a hurry to get off, he neglected to connect them up.

Everything went nicely in the air. But when they came in to land, another plane was just ahead of them. The pilot watched it carefully, taking no chances of running into it. That was an excellent idea. But he was so absorbed in this that he forgot his air speed. And its steady decrease apparently made no impression on him. Which, from the viewpoint of the observer, was distinctly not a good idea.

The latter became more and more nervous. Who was this man, anyway? He knew his name, but nothing about him. He began to wish fervently that he had connected up the set of controls in his cockpit. Sitting there helpless while the plane ran out of flying speed was most uncomfortable. But with the radio set in place he could not get his own stick into its socket.

In a few moments the plane was on the verge of a stall. Another five seconds and it would spin. With the ground only a hundred feet below, there would be no chance to recover. Immediate action was imperative. He could think of only one thing to do, and he did it. He leaned over and planted a clout on the pilot's ear.

Fortunately it had the desired effect. The pilot came to life, pushed the stick forward and picked up speed enough for a safe landing. But the observer maintained

afterward that those few seconds shortened his life at least a year.

To be worth anything, a man's feel of the air must work, not most of the time, but all of the time. No matter what he may be thinking about, he must be instinctively sensitive to flying speed. Any dangerous decrease in it must

Courtesy of Curtiss Flying Service, Inc.

A Private Training Plane.
Curtiss Fledgling with 170 H.P. Curtiss Challenger engine.

send his hand forward automatically. If he has to stop and think about it, he should stay out of the air. It takes hardly a five-second lapse of control to send a plane spinning downward.

But the majority of physically qualified and mentally alert men have the necessary aptitude for flying. Some,

of course, take to it more naturally than others. One man becomes an expert and another only an average pilot. But so long as he has this inborn aptitude, a man has the fundamental qualification for aviation.

However, natural aptitude alone is not sufficient to make a competent pilot. Various other qualifications are likewise essential. Alertness is particularly important. A plane is always traveling at a high rate of speed. Hence the pilot must always know where he is going. Another plane half a mile away may be on top of him in a few seconds. If both pilots should happen to be admiring the scenery below, the consequences might be unfortunate. *Look around* is therefore a fundamental rule of aviation. Alertness is imperative sixty minutes out of every hour in the air.

A newly qualified aviator was flying an HS boat at Hampton Roads. Some of the ships of the Atlantic Fleet were at anchor there, so he went out to play around them. One of the mechanics with him, who was addicted to wing-walking, climbed out on the end of the right wing. He was still young in the air then. And, with the exuberance of a novice, he dived and zoomed merrily around through the Fleet. One big battleship attracted him particularly. He headed for it, stuck his nose down and picked up speed for a zoom alongside it.

Now there was a side wind which he forgot to take into consideration. It blew him in closer to the ship than he intended. And, being interested chiefly in making sure that everybody saw him, he was not so alert as he might have been. The plane did not get too close to the ship itself. But he did overlook a boom projecting from the ship's side. He saw it just as he was pulling the yoke back for a zoom. It was sticking out at exactly the same height as his right

Courtesy of Waco Aircraft Co.

A Race Team of Sport Biplanes.
Waco 220 three-place sport biplanes with 220 H.P. Whirlwind engines.

wing, on which the mechanic was standing. And, in the brief second before he would reach it, he could not tell whether it was long enough to hook the wing. Momentarily he got the impression that it was. He pulled back hard and prayed.

He missed it. But it ended his flying for that day. He headed for home, doing some sober thinking. After landing, he asked the mechanic if they had come close to the boom. His tone, he felt, was properly casual. But there was nothing casual about the mech's reply.

"Yes, sir," he said. "I could have tied a rope on the end of that boom as we went by it."

Carefulness is equally necessary. Nowhere can a careless man get into more trouble than at a flying field. The student is taught all necessary safety precautions. It is then up to him to observe them scrupulously. Minor infractions of regulations such as field rules may sometimes seem harmless. But in the past accidents have resulted from just such things. Constant and consistent carefulness is the only guarantee of an extended career in aviation. Flying is safe only for the man who is willing to fly safely.

An instructor was once scheduled to make a flight with a student in an HS boat. In this type there was a bow cockpit at the extreme forward end of the hull, about ten feet ahead of the wings. The plane was designed to balance with the weight of one man in this cockpit, and since it was so far forward of the center of gravity, it was essential for the required weight to be there. But students were never allowed to carry passengers. Hence on all solo flights three 50-pound sandbags were placed there to balance the plane.

On this particular day, as the instructor was walking

down to the beach, a seaman asked him for a ride. The boy was a big, hulking lad, a recent recruit who had never been up before. He was apparently very anxious to see the world from the air. So the instructor nodded.

"All right. Jump up in the bow there," he said, and went on talking to his student.

They taxied out and gave her the gun. The plane, however, seemed to be very slow in taking off. Finally, by pulling the yoke back almost to his chest, the student got it into the air. But when he tried to let the controls go forward to neutral, the nose started to drop. He had to pull them sharply back. There was something radically wrong with the plane.

The instructor grabbed the controls and cut the gun for a landing. Instinctively he pushed the yoke forward. As he did so the nose dropped like a rock and the plane dived for the water. Full up elevator, the yoke back against his chest, barely checked it in time to keep it from plunging into the bay. As it was, it hit with a jarring thump.

When it came to a stop, the instructor climbed out on the hull to see what there was in the bow cockpit. One look was enough. He nearly fell overboard. There was the big recruit sitting on three 50-pound bags of sand. He was grinning happily, totally ignorant of the fact that he had barely missed going in for a swim.

Of course it was the fault of the mechanic in charge of the plane. He should have taken the sand out when the ship came in from the previous hop, a solo flight on which it had been needed. He had obviously forgotten to do so. But the fact that it was a mechanic's fault never makes it any softer for a pilot who cracks up. The man who wants to keep out of trouble soon finds it an excellent idea to check up on things himself.

Thoroughness is a very useful trait at a flight school. There is a great deal to learn, and only a limited time to learn it in. Time in the air is expensive, and none of it should be wasted. The student cannot afford to lose the value of any of his flights through misdirected effort. Painstaking attention to every detail will meet with hearty approval from the instructor.

Self-confidence is necessary if a student is to solo. He must be ready, when the time comes, to trust to his own ability. The forward cockpit looks extremely empty the first time the instructor stays on the ground. But this must not disconcert him. So long as his previous work has been thorough, he will be able to fly safely. He must know this and, within the limits of his experience, should never hesitate to commence any maneuver. If he flies as he has been taught, the plane will do whatever he wants it to.

But overconfidence is as bad as lack of confidence. And it may easily be worse. For flying can be learned only so fast. Precision cannot be picked up in a few hours. It takes time to learn all the various maneuvers, and the man who tries to force things runs a definite risk. He is likely to learn a lot in a hurry.

A student, unduly enthusiastic, was once unable to wait for his instructor to teach him "flipper turns," turns with the plane banked over more than 45 degrees. Fifteen hours was the regular time for them. But while he was up on a solo flight after twelve hours, he undertook to try one on his own hook. At 3500 feet altitude he banked the plane over. Three seconds later it was in a power spin. He forgot to close the throttle, and it failed to come out. When he finally collected his faculties sufficiently to do this and regain control, the altimeter read 1200 feet. The effect on his enthusiasm was salutary.

Nervousness is to be expected during the first two or three flights. The air is a strange place to the novice. It takes a little time for him to accommodate himself to it. But the feeling should soon wear off. If it does not, and if after ten hours of instruction the controls are still handled nervously, the advisability of a solo flight is questionable.

Nervousness should not, however, be confused with a nervous temperament. The latter, expressing itself in a feeling of tension, is not undesirable. In fact, high-strung students are likely to be alert and quick of perception. They frequently develop into very good pilots.

There is one other qualification which is of great importance. It is known to instructors as manner in emergency. No pilot can fly indefinitely without meeting situations where rapid and accurate handling of the plane is required. It is imperative that he be able to meet these situations. He can do so only if he can work coolly in a tight place.

Manner in emergency is tested regularly during flight training by creating artificial emergencies. The instructor, for instance, closes the throttle unexpectedly to simulate engine failure. The student must take prompt and effective action. The great majority of students meet these tests satisfactorily. But a certain number are always found who fail to do so. Though they may be able to fly well under normal conditions, emergencies disconcert them. They hesitate, misjudge distances and are likely to lose control. Needless to say, a student of this type cannot be considered qualified for a pilot's license.

This work is probably the least monotonous part of an instructor's duties. When the throttle is closed, there is no telling just what a student will do. Consequently the instructor's hand is never far from the stick. Not infre-

quently he has to use it very hurriedly, as we shall see in a later chapter.

Finally, there is particular need in aviation for a quality required equally in every other profession—ordinary common sense. After an instructor has taught a student everything he can, after the student has perfected his work by constant practice, after he has passed his tests and gotten his license, he is still not a good pilot unless he has good sense. No one can tell him exactly what to do and what not to do in the air, for the possible situations which might confront him are infinite. He must have some judgment of his own in order to meet those things which actually do happen to him. If he lacks what other pilots consider proper discrimination, if he is constantly doing reckless and unnecessary things, he is forthwith labeled as "dizzy."

One day, standing on a street corner at an air station, an instructor heard the engine of an approaching plane. As he looked up, a visiting plane from a distant field flew by close overhead. The throttle was wide open and the pilot was looking down over the side as it raced past, scarcely a hundred feet above the roofs. He stood and watched, astounded. Not only was such action contrary to all regulations, but it was a foolish thing to do. Of course there was not one chance in ten thousand that the engine actually would stop just then. But if it did, nothing could keep the plane from crashing into a building. And, flying low, there is always just a possibility of failing to see something sticking up from the ground. Good pilots do not do that sort of thing.

As he watched, the plane swerved slightly. Its wings came into line with a radio mast. He was momentarily puzzled, wondering how it had gotten beyond the mast so quickly. Then, even as the truth flashed into his mind,

the crash came. The top of the pole was snapped off, while the plane, its right wing shattered, lunged wildly upward and turned over on its back. Then it dropped from sight behind a building. The pilot, idly watching the ground, had turned straight into the mast.

He was not present at the board of investigation.

If a man has veritable genius for flying; if he is cool, confident, fearless; if he performs feats of unexampled brilliance; still, if he lacks common sense, he is not a good pilot. He has never learned the truth of the old saying, "I'd rather be the oldest living pilot than the best one."

Nothing that has been said is intended to give the impression that flying is very difficult to learn. This is not the fact. But aviation differs radically from other outdoor activities in one way: it must be done well or not at all. A man can take a few lessons in golf and then go out on the links by himself. If at first he slices his drives and misses his putts, that does not matter. He can take a year to learn in if he wants to.

But not so in aviation. The law of gravity makes no provision for first offenders. When you once get into the air, you either fly or you do not fly. And if you do not fly, you come down abruptly, forcefully and at once. The air is not the place for a dub.

Therefore, when a man decides to go in for aviation, he must make up his mind to put the necessary time and effort into it. He must follow his instructor's orders implicitly. And he must stick to it until he can fly, not passably, but well. But so long as he does this, flying will involve no danger and no undue difficulty.

CHAPTER VI

THE MODERN TRAINING SCHOOL

It has been said that learning to fly is very little harder than learning to drive a motor car. Anyone making such a statement can hardly have piloted a plane himself. Certainly he has never been an instructor. For he obviously has no idea of the painstaking effort required in the training of a student. To produce a really capable pilot requires constant work over a period of many weeks. Flying is not to be picked up in the spare time of a few days.

Nor is such an idea merely wrong. It is actually dangerous. In the past many accidents have been caused by it. Schools where there was no real understanding of the principles of training guaranteed to turn out competent pilots in ten hours' time. Not infrequently their instruction was dangerously inadequate. But students believed them. And when they got into the air alone, they assumed that they knew all about handling a plane. They proceeded to fly around with the casual confidence of veterans. The only remarkable thing is that there were not more crashes.

It is perfectly true that the average student can solo safely after ten hours of instruction. But he can do so only when his training has been scientifically planned, and when it has been carried out under guidance of an experienced and thorough instructor. And even then he is not yet a competent pilot. He has a great deal more work to do under the eye of his instructor before he is fully capable

of taking care of himself. Training can be slighted only at the expense of safety.

But there is nothing mysterious about flight training. It is simply a matter of correct principles. Certain things must be taught. And they can be learned best in certain ways. So long as the instructor applies these principles properly and so long as the student follows his directions conscientiously, the result is a foregone conclusion. The student learns to fly safely.

So the man who has decided to go into aviation, either as a profession or from personal interest in it, should approach flight training with this viewpoint. A course in flying is no stupendous task. But neither is it to be taken lightly. It will require sustained effort. But if he takes the necessary time and does devote this effort to it, he can expect to become a capable pilot.

An aviation training school includes a ground school and a flight school. The student commences his work in the former. Here he studies the theory of flight, the principles of which were outlined briefly in Chapter III; the construction, operation and maintenance of aircraft and of engines; the Air Commerce Regulations of the Department of Commerce, including particularly the Air Traffic Rules, the rules of the road for aircraft; and, if he is going to be a transport pilot, the subjects of Meteorology, the science of the weather, and Aerial Navigation, flying on a course by use of the compass. His work on planes includes both classroom lectures on principles of construction and practical rigging work in the hangar. The study of engines likewise embraces both the theory of construction and practical work in the shop.

Provision is made by the Department of Commerce for the examination of ground and flying schools, and for their

rating as private pilot's schools, limited commercial pilot's schools or transport pilot's schools. On application from a school, inspection is made of the adequacy of its course of instruction, the suitability and airworthiness of its equipment, and the competency of its instructors. If it meets the Department's requirements in all respects, a certificate is issued designating it as an approved school in its class. Such certificates are optional, not being required by law. But it can be assumed that all responsible schools will comply with the Department's requirements and secure a certificate.

When ground school work is started, the student should also commence the study of a text-book on flight training. This will not teach him to fly. But it will tell him how to go at it to learn to fly. Its importance lies in the fact that, when he gets into the air, things will happen rapidly. If he has no previous idea of what to expect, he will probably become confused. This results in misdirected effort. He moves his controls erratically, even aimlessly, trying to hit the right combination by pure chance. Thus much of his time is wasted.

On the other hand, if he has studied the principles of the various maneuvers and knows the proper sequence of control movements in each, he can direct his efforts intelligently. While he cannot fly at once, he quickly learns to recognize his mistakes and knows how to correct them. He is able to go at his work effectively. Careful preliminary study of practical flight training should double the value of actual instruction in the air.

After a week or so of ground study, the student is familiar enough with planes and engines to commence flying. Thereafter he continues his ground school work during a part of each day until he completes it.

During the early years of aviation, flying was taught by the Penguin method. Primary training planes, called penguins, were built with wings so short that they would barely rise into the air. After taxi-ing one of them around

Courtesy of Davis Aircraft Corp.

A High-wing Light Monoplane.
Davis V-3 two-place monoplane with 65 H.P. LeBlond engine.

on the ground for an hour or so, the beginning student started off on his first flight. He was alone, knowing about flying only what his instructor had told him orally. With the throttle wide open, the penguin would hop off the ground a few feet and struggle along. The student tried

to stay up twenty or thirty seconds in straight flight. Then, if he were still in the air, he closed the throttle and flopped back on to the ground. This process he repeated over and over again until he gained some idea of the rudiments of control. Then he was ready to go up in a slightly more powerful plane, which would take him up a hundred feet or so. Here he tried a turn, and presently learned to circle the field and get back into it. After a while he was promoted to full-powered training planes; and eventually, if he was born to fly, he became a pilot. It can readily be imagined, however, that not all students succeeded in learning to fly by this method.

In the modern school, no such primitive means are employed in the training of students. Instead, all planes are equipped with dual controls—two sets of controls in different cockpits connected together so that the plane may be flown from either position. The instructor goes up with the student, occupying the forward cockpit while the latter sits in the rear. Thus the instructor can demonstrate practically the operation of the controls and can correct the student's errors. There is no possibility of loss of control, because he can take command at any instant. It is necessary only to have signals so that the student will know when to take his stick and when to let go of it.

Ten hours is the normal amount of dual instruction, and one hour a day the usual rate; a flight of 45 minutes is enough, but if practicable the time should not be less than an hour. And, weather permitting, flights should be made daily for five days a week. A lapse of several days without a flight retards progress.

The following is a typical course, in general plan similar to the course adopted in the Navy for the elementary training of pilots. It includes ten hours of dual instruction and

thirty hours of solo flying, with instruction flights after each five hours. Each maneuver is given under the hour in which it is commenced. Thereafter it is practiced on every flight (except that stalls and spins are not practiced on solo flights until after twenty hours).

COURSE OF FLIGHT TRAINING

I. Dual Instruction.

First hour	Taxi-ing.
	Straight flying.
	Turns.
	Glides.
Second	Take-offs.
	Climbing.
	S-turns.
	Leveling off for landings.
Third	Landings, use of elevators only.
Sixth	Landings, use of ailerons and rudder.
	Spirals.
	Approaches.
	Elementary forced landings.
Ninth	Stalls and spins.

II. Elementary Solo Flying.

First solo.—Five-minute flight, necessary turns, one landing.

First 5 hours.—Take-offs, turns, landings.

Instruction flight.—Instruction as necessary, including spins; power stall landings (seaplanes only).

5 to 10 hours.—Take-offs, turns, spirals, landings.

Instruction flight.—Instruction as necessary, including spins.

10 to 15 hours.—Same as 5 to 10 hours.

III. Advanced Flying.

Instruction flight.—Reverse control turns and spirals, sideslips, power spins.

15 to 20 hours.—Take-offs, turns, spirals, landings, reverse control turns and spirals.
Instruction flight.—Stunts.
20 to 25 hours.—Stunts, with 20 minutes of each hour on elementary work.
Instruction flight.—Precision landings, figure-eight turns, wingovers.
25 to 30 hours.—Precision landings, figure-eight turns, wingovers.
Final instruction flight.—Review; instruction as necessary.

As indicated, the student does not attempt to make complete landings immediately. At first he tries simply to level off at the proper height. Then, during the third hour, he commences to handle the elevators, while the instructor holds the plane straight with the ailerons and rudder. Not until the sixth hour are the latter turned over to him. His training in forced landings is given by simulating motor failure. The instructor closes the throttle unexpectedly and the student must assume that the engine has stopped. When he has done his best, the instructor can reopen the throttle and go on before there is any danger of damage to the plane.

On completion of his ten hours of dual instruction, the average student is ready to solo—to go up alone. This he does immediately. The flight is short, lasting only five or ten minutes. But for him it is very important. It marks this date as a red-letter day. He is now an aviator.

But, though he is an aviator, he is still not a qualified one. His course is far from being over. For one solo flight does not make a competent pilot out of even the ablest student. Many hours must be spent practicing the elementary things already taught. And there are many new things to be learned.

Fifteen hours is the time usually allowed for practicing

take-offs, turns, spirals and landings. Daily flights of about an hour should be made. After each five hours, the instructor goes up to check the student's work. These flights are essential. For the latter's flying when he soloed, though safe, was far from perfect. It is important to see what he has been doing during his solo time. For if he is still mak-

Courtesy of Aeromarine Klemm Corp.

A Low-wing Light Monoplane.
Aeromarine Klemm AKL-25 two-place monoplane with 40 H.P. Salmson engine.

ing elementary mistakes, he cannot progress properly until they are corrected.

On the instruction flight after fifteen hours solo, advanced work is begun. Reverse control or "flipper" turns and spirals are first tried. In these, the plane is banked over more than 45 degrees. After an hour's instruction, the student is ready to practice them during the next five hours solo.

After twenty hours, instruction in stunts is given, pro-

vided the student desires them. They are not essential for safe flight. But they familiarize him with unusual positions of the plane and develop his self-confidence. Stunts are practiced during the succeeding five hours.

At twenty-five hours training is commenced in precision landings. During all of his preceding solo work the student has been developing his ability to land accurately. But now his attention is concentrated on this point. Landings are made in smaller fields, where precision is needed to get in at all. Approaches are practiced both with and without use of the engine. If practicable several hours should be spent in this work, separated by brief periods of solo flying. Ability to land accurately is of the greatest importance, and no pilot can be considered competent until he can do so.

Completion of this course does not produce an experienced pilot. Additional time must be spent in the air before a commercial license can be secured. But after the instruction outlined here a man should, if necessary, be able to go on with his own training. However, an advanced course in transport flying, if it can be taken, will be of great value.

Perhaps the course outlined here looks complicated. Possibly the latter part of it appears unnecessary. A man may say that he wants only to fly along quietly, that flipper turns and precision landings do not interest him. But suppose he is cruising along and just ahead of him another plane suddenly appears. Does he want to go careering into it because he cannot turn sharply? Or suppose, going from one airport to another, he gets caught in storm or fog and has to land. Or perhaps something goes wrong with the engine. The fact that he would like to cruise quietly along is now quite irrelevant. He is going to take an interest in precision landings whether he wants to or not.

An instructor was one day checking a student in the latter part of a landplane course. As a matter of routine, he took him over to a small practice field and told him to make a landing in it. To his surprise, the student apparently did not know how to go at it. Instead of circling around it for a proper approach, he flew over it, looking down at it hesitatingly. Right over it he started to turn. The turn was poor. But in his uncertainty he failed to realize this. Within five seconds the instructor had to take the stick to keep out of a spin.

He landed in the field and stopped, in order to find out what the trouble was. As he had guessed, the student had never been properly instructed in precision landings. Under the circumstances, although it was not supposed to be part of a check flight, he decided to give him some instruction. That was all the student needed. Within an hour he was able to shoot a short field reasonably well.

A week later, on a cross-country flight, he was one of a number of students who got lost in thick haze. He had to pick an emergency field and land in it to find out where he was. Had he tried to get into it as he did on the check, the newspapers next day would very likely have carried an account of a crash "due to unknown causes." Instead he made a good landing.

Reverse control turns and precision landings have been referred to as a part of "advanced" flying. But this is simply for convenience in distinguishing them from the elementary maneuvers learned before solo. It does not mean that they are optional. There is no question as to whether or not a man wants to learn them. He must learn them before he can consider himself a pilot. And the only safe way to do so is under the immediate guidance of an instructor.

It is, of course, true that in the past pilots have taught themselves advanced maneuvers. This is by no means impossible. But it is most certainly not advisable now that complete courses are available at reasonable rates. Self-instruction in other professions—medicine, engineering, law—has long ago given way to the more effective method of training in properly organized schools. And in aviation adequate training is peculiarly necessary because of the risk involved in attempting maneuvers without proper preparation. While the longer course is more expensive, the additional cost is negligible compared with what it might be in case of a serious mistake. All advanced maneuvers can be learned safely, but only when they are properly taught.

CHAPTER VII

THE FLYING FIELD

When the student first goes out to the flying field, he sees a large, flat piece of ground entirely bare of obstacles. It is sometimes grass-covered, as this makes the best surface for landings. However, the runways, at least, are likely to be worn clear of grass. On one side are the hangars, shops, offices and other buildings. At fields where elementary training is carried on, the other sides should be clear. There should be no other buildings immediately adjacent, nor any other large obstacles, such as high trees or wires. Students need plenty of room.

Along one side of the field is the operating line. On this planes are placed when they are rolled out of the hangar, wheels all on the line and facing the field. Here engines are warmed up and final inspections made. And when ready to start, instructors and students get aboard here. After a flight, planes are always brought back to the operating line.

If it is a seaplane station, planes are sitting on four-wheeled handling trucks, whose padded frames fit their floats. When ready to start, they are pushed over to the head of a runway. Down this they are allowed to roll. When a plane hits the water, it floats clear of the truck, which is weighted to keep it on the bottom. The latter is then hauled out with a line. When returning after a flight, planes are run up on the beach. Here, with their floats aground, they can be held with lines while crews are changed. Then they are swung around and headed out

again. On completion of flying, planes are brought to the runway, where their trucks are slid under them. A tractor then hauls each truck out with its plane on it.

Somewhere in the vicinity, frequently on top of a hangar, the student will see a pole from the top of which a cylinder of white cloth is suspended. This is a wind-sock. It is eight or ten feet long, and tapers from a diameter of two or three feet down to about half of that. At the larger end is a hoop, from which lines are run securing it to the pole. The wind, entering the larger end, distends it. It straightens out parallel to the wind direction, and swings around with every shift. It is easily visible from the air, and tells pilots coming in the exact direction of the wind.

There will also be a tee. This is a structure of boards, painted white and usually movable, in the form of a letter T. Its shank is parallel to the direction in which landings should be made, while its crosspiece is at the end of the shank toward which the plane should be headed. That is, when the plane touches the ground, its fuselage and wings would be seen by an observer overhead in exactly the same relative position as the shank and crosspiece of the tee. The latter is usually kept headed into the wind. But it may sometimes indicate a runway which is at a slight angle to the wind direction.

Sometimes a flag, either white or red, will be seen flying from a pole. This is to indicate that, in the vicinity of the field, planes may turn in one direction only. A white flag indicates that all turns below 1000 feet altitude must be made to the right. A red flag requires left turns. The purpose of this is to eliminate any danger of collision due to planes meeting head on.

Where a number of planes are operating at the same time, field rules are often found necessary. Zones for take-offs

Courtesy of Curtiss Flying Service, Inc.

A Three-place Cabin Monoplane.
Curtiss Robin with 90 H.P. Curtiss OX-5 engine.

and landings are then prescribed, and indicated by markers. Planes leaving the operating line must taxi to the proper zone before taking off. When returning, they must land in another zone. Other field rules are made to suit particular circumstances.

No one should walk out on the field beyond the operating line. There is danger of being hit by a plane taking off or landing.

Time spent in the air, by both planes and pilots, is carefully recorded. The standard measurements of aviation are in terms of hours and minutes. Rates and costs are figured on an hourly basis. Overhauls of planes and engines are scheduled by operating time. And a pilot's experience is considered as being based on hours in the air. He must meet certain time requirements before he can get a license.

Time may either be recorded on individual plane record sheets by mechanics or, when many planes are flying, may be entered in a daily flight log book. For each flight there should be shown the plane number, instructor, student, time of take-off, time of return, character of flight and any other pertinent remarks. Individual log books are kept for each plane, each engine, each instructor and each student, in which entries are made from the daily log book.

Incidentally, it is an excellent idea to check up on the entries in the flight log book, and also to see that they are correctly transferred to one's personal log book. No time should be counted as instruction time except that actually devoted to instruction. If the instructor takes the controls for more than a minute or two for any other purpose, such as to test the alignment of the plane, he will count this as test time. If it is necessary to stop more than five minutes for repairs during a flight, the timekeeper should be notified to deduct this time. The student is entitled to a full ten

hours of instruction, and it is up to him to see that no mistakes get into his log book.

Before his first flight the student must have the necessary flying gear. This includes helmet, goggles and, except in warm weather, a jacket or flying suit. Goggles must always have nonbreakable lenses. A student's helmet of very heavy leather, called a crash helmet, is desirable. It affords protection to the head in case of minor accident. Lined leather clothing is often worn in cool weather, as it keeps out the wind. Leather gauntlets are also used. In winter fur-lined clothing is comfortable.

A Gosport helmet is very useful during dual instruction. This is a crash helmet with phones in the ear flaps. From these a voice tube runs to a mouthpiece through which the instructor can talk. His voice is somewhat difficult to hear with the engine running. But when the latter is throttled down for landing, it is clear. As this is the time when detailed coaching is most needed, a Gosport greatly facilitates instruction.

The typical training plane is a slow, comparatively low-powered biplane, though a monoplane can also be used successfully. The engine may be anywhere from 60 to 200 H.P. But the wings are always large in order to give it a low landing speed, and hence it is slow. However, speed in the air is of no particular value, while a landing speed of not over 40 miles an hour is essential. The plane is of particularly rugged construction in order to stand the kind of landings students make when they first try it.

Open cockpit planes are always used for elementary training. It is important for the student to be out in the open where he can feel what the plane is doing. He should not try flying a cabin plane until after he completes the course.

The instrument board of a plane contains a variety of

dials and gauges. These are classed as flying instruments and engine instruments. Included in the former are the altimeter, which registers the height of the plane; the air speed meter, which tells the speed through the air; the turn indicator, which shows when the plane is turning right

Courtesy of Ryan Aircraft Corp.

A Six-place Cabin Monoplane.
Ryan Brougham B-5 300 H.P. Whirlwind engine.

or left; the inclinometer and fore-and-aft level, curved glass tubes containing liquid and a bubble; and the compass. The engine instruments have already been described in Chapter IV. Besides these, there are dials, gauges and valves varying according to the make of plane. And on the left side of the cockpit are the throttle and spark levers.

In the student's cockpit there should never be any flying instrument except the altimeter. Under no circumstances should an air speed meter or inclinometer be visible to him.

At first thought, this seems opposed to common sense. If speed is so important, why should not the air speed meter be the most important instrument in the plane? But, if the reader will recall Chapter V, he will remember the stress laid on flying instinct. A man must have the feel of the air in order to fly safely. But this does not depend on instruments. It depends on development of natural sensitiveness to air speed. And if a student is allowed to use an air speed meter, he will come to rely on it instead of on his instinct.

Suppose now he wants to make a landing in a small field. He has to approach close over some trees at comparatively low speed. If he depends on the air speed meter, he must keep glancing at it every second or two, then looking back at the field. In actual practice, any accuracy at all under those conditions would be impossible. And the chance of losing control in between glances at the instrument board would be excellent. No more dangerous kind of flying could be conceived than trying to fly by an air speed meter.

On the other hand, when a man has no instruments to depend on, he is forced to develop his feel of the air. Then when he comes to make precision landings, he can depend on it. He is able to concentrate his attention on the field, knowing that he will instantly feel any dangerous diminution in speed. The student who has never seen an air speed meter can fly with twice the safety of the man who uses one.

For qualified pilots, all flying instruments have important uses. But a man must learn to fly first before he can safely use them. Except for the altimeter and the compass, they

should never under any circumstances be in the student's cockpit of a training plane.

Here a suggestion to the beginning student may be timely. Before going up for your first instruction flight, it will be a good idea to climb into a plane and sit there for a few minutes to familiarize yourself with the cockpit. First get permission to do this, and have the mechanic in charge of the plane show you where to step, so you won't put your feet through anything. Get into the rear cockpit, and note the position in which you will be during flight. You will find the stick directly in front of you, between your legs. Your feet rest on the rudder bar. You should be high enough so that your head projects well out of the cockpit, but not too high. A piece of line run along the top of the fuselage cowling should be about level with your chin. Cushions as needed must be used to raise you to the right height.

The edges of the cowling all around you are protected with heavy leather-covered padding. A windshield will deflect the stream of air from your face. The instrument board is in front of you, and the throttle and spark are at your left.

Now try moving the stick and rudder bar gently. Your position should be such that you can do this without effort. Only the elbow and shoulder should be used in moving the stick, and only the knees in moving the rudder bar. Any necessity for leaning forward to reach the stick or for moving the hips to operate the rudder means that you are too far back. You must then put a cushion behind your back.

You will find that there is a safety belt to fasten around your waist. This is a broad belt, six or eight inches wide, with a patent buckle which will hold securely but which

can be unfastened with a flick of the hand. Its purpose is to hold you in your seat in case you perform any unexpectedly vigorous maneuvers with the plane, or later on when you try stunts.

As you sit in the cockpit, the movement of the stick and rudder bar may seem awkward and unnatural to you. You

Courtesy of Ryan Aircraft Corp

INTERIOR OF A CABIN MONOPLANE.
The pilots' seats and dual controls of a Ryan Brougham.

wonder if you can ever learn to handle a plane with them. And if an engine nearby is filling your ears with its roar as a pilot tests it out, you imagine that sitting right behind a racket like that will completely disconcert you—particularly with the propeller blowing wind past you at sixty miles an hour.

But you need not worry about that. With helmet buckled around your head and covering your ears, the engine will not bother you. The windshield will protect you from the direct blast, and your goggles will cover your eyes. The strangeness will wear off after a few minutes in the air, and then you can concentrate on handling the controls. It will not be long before you will find yourself using them quite naturally.

As you walk around the flying field, you will hear various terms which are new to you. You will learn all of these later. But a number of them are worth learning right away.

A plane is often referred to as a "ship." And its running engine is the "gun." The latter is not an exact term, being usually used in a phrase. To "give her the gun" is to open the throttle, while to "cut the gun" is to close the throttle. "Full gun" means with throttle wide open, while a "shot of the gun" is a brief burst of the engine in a glide. A flight is a "hop," and a mechanic is a "mech."

The elevators are familiarly known as "flippers," and the propeller is the "prop." When you start the engine, "contact" means that the ignition switch is on. After you test it out, if it registers 1700 revolutions per minute you tell the instructor that it "turns up 1700 revs." In case the engine should stop and leave you stranded out in the middle of the field, your impotent propeller would be a "dead stick."

When you approach the field to land, you make a "pass" at it. If you come in too high, you "overshoot." If you are too low, so that the instructor has to give her the gun to reach the field, you "undershoot." When a pilot damages a plane sufficiently to prevent its being flown until repairs are made, he "cracks up." If the plane is beyond repair, it is a "washout." But, though you will overshoot and undershoot more or less frequently, if you never fail to give her

the gun in time, you are not likely to be responsible for any washouts.

One final admonition. Whenever you are on the field, there is one thing you must always remember. *Look out for propellers.* The tip of even an idling propeller is revolving at over two miles a minute. And it has a knife-like edge. You must keep away from it. Never walk near planes with your eyes on the ground. Never approach a plane without looking particularly at the propeller. Never climb over the leading edge of the lower wing while the engine is running. Needless accidents have occurred through neglect of these precautions. Make up your mind now that you will remember them.

CHAPTER VIII

PREPARATIONS FOR DUAL INSTRUCTION

The student should always go up as a passenger first, before his dual instruction is commenced. This will familiarize him with the sensation of being in the air. The cockpit of the training plane will not then seem such a strange place, and he will not waste any instruction time becoming acquainted with it.

If he has already been up before he arrives at the flight school, he is prepared to begin his dual work. But if he has not, he should arrange to go up once or twice on familiarization flights. At Pensacola, this is regular routine for any students who have not previously flown. Such flights should always be made in an open cockpit plane. A flight in a cabin plane does not give the necessary experience.

The student climbs in, seats himself, and buckles his safety belt. The pilot tests out the engine on the operating line. Then he taxies out into the field. After a look around to see that everything is clear, he opens the throttle for the take-off.

The student's first impression of flying will probably be a confused blur of roaring speed. He is out in the open, protected only by the cowling and a small windshield. The latter deflects the direct force of the wind whipped past him by the propeller at more than a mile a minute velocity. But eddies swirl around his head. The stubby exhaust pipes do nothing to deaden the staccato racket of the engine, and

the cylinder explosions blend into a sustained roar as it is opened up to full speed. This roar, drowning out all other sounds, continues throughout the entire flight. It cuts him off from other noises as if by a wall.

The fuselage is vibrating under the impulse of racing connecting rods. A taut thrumming runs through the cowling on whose padded edges his hands are resting. This is punctuated by heavier jars as the wheels hit little roughnesses in the ground. The jars increase as the plane picks up speed, though if the surface is good they are never excessive. Looking out ahead past the engine, he sees the ground sliding toward him. Beneath the wings, it is flowing past like a brown torrent. The plane is skimming over it faster and faster.

In a few seconds the jarring fades away. One or two little ticks, and then it is gone. A smooth patch of ground, the student thinks. Then he is suddenly aware that the field is dropping away. The plane has detached itself from the earth so smoothly that he was not even aware of it. But here he is, in the air.

The thing which now impresses him most will probably be the smoothness of it. On a quiet day, not even the best concrete road could be as smooth. There is not the slightest shock. The plane sails along as effortlessly as a bird. Now and then it may sway a little to one side or the other. But a touch of the pilot's hand swings it easily back. There is never the slightest jerk or jolt or heave. Flying is fluid in its smoothness.

On a gusty day, however, there may be more apparent motion. The plane will pitch and roll somewhat like a boat in a choppy sea, though seldom with the same violence. But now and then definite jolts may be felt. It may rise or drop sharply, producing momentarily a sensation like an

elevator starting. However, there is no discomfort, and control cannot be endangered.

The new perspective is puzzling. At first things look quite unfamiliar. The sudden change of scale and the different angle at which they are seen give them a strange appearance. And in the greatly expanded radius of vision, particular objects can be located only with an effort. Seen from above, the world looks totally different. The aviator has in actual fact a bird's-eye view. However, it does not take long to get used to this.

There is no feeling of dizziness in the air comparable to what some people feel when looking down from a high building. This is due to the fact that there is no visual connection between the plane and the ground. It is the lines of the building, leading downward and suggesting height, which produce the sensation of dizziness. But from a plane, the earth appears to be simply a flat surface above which the plane is suspended. Any one can look down without the slightest fear of becoming dizzy.

If he is not prepared for it, the first bank may startle the student for a second. The plane tilts to one side. Looking along the low wing, he sees it pointing earthward at an appreciable angle. He may catch his breath slightly. People have even leaned involuntarily toward the other side. But in a good turn there is no more tendency to fall inward than when leaning over on a motorcycle rounding a corner. No effort is required to sit upright in relation to the plane. And since the bank shows no tendency to increase, the student's start is only momentary.

After a little while the student becomes accustomed to the wind and the noise, and finds that they cause him no discomfort whatever. His eyes are protected by his goggles. His helmet covers his head and comes down over his ears.

If he wants, he can put cotton in the latter to further cut down the noise of the engine, though this is not necessary. Once he has gotten used to the wind and the drone of the

Courtesy of Fairchild Aviation Corp.

A Cabin Monoplane Flying Over the Andes.
Fairchild 71 seven-place monoplane with 425 H.P. Wasp engine at 10,000 feet altitude over the Peruvian Andes.

motor, he forgets them in the interest which he finds in flying.

It will be a good idea for the student to note now whether his flying gear is suitable, as to both warmth and fit. Helmet and goggles should be neither too loose nor too tight. If

too loose, wind will get inside them, which is disconcerting. If too tight, a headache will result. They should be adjusted until they fit comfortably. Clothing should not be tight enough to interfere with free movement of the arms and legs, but if loose it may be heavy.

When it is time to land, the pilot throttles down the engine. At the same time he drops the nose into a glide. With the roar of the motor stilled, the wind can be heard whistling past the wings and fuselage. The sound is always loud, for speed in a glide is important. The ground begins to come up. The hangars grow larger. The field looms closer and closer until the student imagines the plane is on the verge of plunging into it. Then a slight movement of the stick levels it off and it skims across the field just above the surface. Finally, with a slight jar, it drops onto the ground and rolls along, gradually losing its speed until it comes to a stop. That is the first flight.

On the day when he is to start his dual instruction, the student reports to the field at the designated time. If he is commencing training with a class, there will very likely first be a short talk by the Chief Instructor. This will not, however, be an oratorical effort. The Chief Instructor has little time to spend on sentiment. His business is to teach students to fly. And what he has to say is designed purely to further this purpose.

It will perhaps include a brief word of welcome to the school. But primarily it will deal with what the student is expected to do. There will be an explanation of the daily routine. And the field rules will be outlined in detail, with particular emphasis on the most important points to watch. Any special school regulations will be called to the attention of students. And probably there will be a few concluding

words on safety precautions. The Chief Instructor knows that the first day is not too soon to begin hammering away on this subject. What he says may not all be remembered now. But the necessary precautions must be learned before solo.

Next each student will be assigned to an instructor. The latter will first take a few minutes to get acquainted. He wants to know how often the student has been up before and whether he has handled the stick at all. He is especially interested in what the student knows about practical flying. If the latter is totally unfamiliar with it, he must commence with an explanation of fundamental principles. On the other hand, if the student already knows something about flying from previous study, it will save the instructor much time and effort, a favor which he will appreciate.

At this time the instructor will go over the terms generally employed in designating control movements and the signals commonly used in the air. Movements of the control surfaces are referred to as follows:

1. Up elevator—movement of elevators to raise nose.
2. Down elevator—movement of elevators to depress nose.
3. Right (or left) aileron—movement of ailerons to bank to right (or left).
4. Up (or opposite) aileron—movement of ailerons to decrease, or to prevent an increase of, a bank.
5. Right (or left) rudder—movement of rudder to swing nose to right (or left) or to keep it from swinging to left (or right).
6. Opposite rudder—application of rudder opposite to a bank; that is, right rudder if in a left bank.

A system of signals is always used by the instructor to direct the student in the air. Even if the latter wears a Gosport, with the engine running they are more satisfactory than vocal directions, though the Gosport is best in landing. The following signals are frequently used:

SIGNALS FOR MANEUVERS

Signal	Meaning
1. Stick shaken laterally, both hands held up.	Control turned over to student.
2. Stick shaken laterally, one hand tapping helmet.	Control resumed by instructor.
3. Arm held out laterally horizontal.	Turn toward that side.
4. Forearm vertical, motioning ahead.	Resume straight flight.
5. Hand pointing upward.	Climb.
6. Downward motion of arm.	Land; if not headed directly upwind, spiral and land.

CORRECTION SIGNALS

In straight flight or turns:	
1. Hands held up, palms upward and motioning upward.	Raise the nose slightly.
2. Hands held up, palms downward and motioning downward.	Drop the nose slightly.
In turns:	
3. Arm held out laterally toward inner wing; palm of hand up and motioning upward.	Decrease the bank.
4. Same, palm down, motioning downward.	Increase the bank.
5. Same, fingers extended parallel to wing.	Bank is correct.
6. Tapping outside cheek with palm of hand.	Wind felt on outside cheek, plane is skidding.
7. Tapping inside cheek with palm of hand.	Wind felt on inside cheek, plane is slipping.

It is well to be sure that these signals are understood before training is begun. A new instructor was flying along with a student during the latter's first hour. Somewhat inexperienced, his explanation of signals had been hasty and not entirely clear. The student was showing a consistent tendency to let the plane tilt over toward the right—dragging the right wing, a pilot would call it. The instructor had been correcting this with the proper hand signal. But the student's response was slow. Finally, to emphasize the correction, he hit the stick sharply. What was his astonishment when the nose dropped abruptly and the plane pitched into a dive earthward. Grabbing the stick, he straightened out, closed the throttle and landed.

"What are you doing, letting the plane go into a dive like that?" he demanded.

"Why, you hit the stick and I thought you wanted me to let go of it," the startled student replied.

After going over signals, the next thing is to inspect the plane. This is a matter of routine which must never be neglected. The mechanic in charge is supposed to see that everything is in perfect condition. But he is not in command. It is the pilot who is going up. And it is he who is responsible. Before he leaves the ground he should know that the plane is in every way ready for flight.

In 1918 an instructor was taking off in a seaplane. As it left the water, it struck a gust of wind and the right wing dropped. The pilot, of course, moved the wheel to the left. But the wing dropped farther. Instinctively he pulled the wheel over sharply. With equal abruptness the wing went down into a steep bank. Its tip touched the water. After the ensuing shower of spray had subsided, the instructor climbed, wet and disconcerted, out of the wreck.

LIBRARY

On inspection it was found that the aileron wires were crossed. A rigger, working on the plane, had connected them up improperly. The result was that, when the pilot made what would normally have been the proper movement of the wheel, he tilted the plane farther over instead and spilled himself into the bay. Confronted with the evidence,

Courtesy of Stearman Aircraft Co.

A Mail Plane Over Mid-Western Plains.
Stearman M-2 with 525 H.P. Wright Cyclone engine.

he could hardly avoid the admission that he had forgotten to test out the controls before flight.

Another pilot was one day scheduled to make a flight in a big bombing plane. He arrived late, jumped hastily into the cockpit, started the engine and took off. On getting into the air, he found the plane apparently out of balance.

The tail was very heavy. It wanted to sink, and in order to keep it from doing so he had to hold the controls well forward. This involved so much strain that he soon came down again.

After landing, he jumped out to look over the plane. As he did so, a seasick mechanic emerged unsteadily from the rear cockpit. He had been working back in the tail, tightening some loose wires. He had of course heard the engine start. But the pilot had taken off before he had had time to get out. With the plane pitching in bumpy air, he had not dared to climb forward through the fuselage for fear of accidentally putting his foot through the fabric. Clinging to the brace wires, doubled up in the confined space, with the plane's motion much accentuated here so far back of the center of gravity, his digestive organs had failed to stand the strain. The look he now gave the over-hasty pilot was extremely reproachful.

So it is an excellent idea for the student to start inspecting the plane from the first day he commences flying. His ground school work has given him enough information to do this. The actual responsibility at this time of course rests on the instructor. But the student hopes to solo before long. And habitual carefulness should be developed before then. If he makes inspection an invariable routine now, he will not forget it later.

While inspecting, the student should not forget to see that the wheels are blocked. The wooden blocks placed in front of them are necessary to keep the plane from rolling ahead when the engine is first started. In the case of a seaplane, the wheels of the truck must be blocked.

When the student gets into the cockpit, the instructor will see that he sits in the proper position, with cushions as

necessary under and behind him. And also he will see that the student buckles his safety belt. This must never be forgotten.

The instructor now climbs into the forward cockpit. On this first flight he will probably start the engine himself.

Courtesy of Boeing Airplane Co.

A Mail Plane Over the Rocky Mountains.
Boeing 40-B2 with Pratt & Whitney 525 H.P. Hornet engine.

But the student should watch him carefully to see how it is done. First, the main gas valve is opened and pressure pumped up by hand. The engine is then primed by use of a primer. If there is an inertia starter the mechanic will turn this over with a crank. When ready to start, the pilot calls out "All clear." He must then see that every one is clear of the propeller. When sure of this he calls "Contact," and turns the ignition switch on. Then he throws in the starter clutch. This turns the engine over, and ordinarily it starts.

In case it fails to start the first time, the switch must be thrown off again. It is dangerous to leave it on except when the engine is running. Otherwise some one may move the propeller and the motor may start unexpectedly. Whenever he is in the cockpit, the student should always see that the switch is kept turned *off* while the engine is not running.

As soon as the engine is warmed up, the instructor tests it out. When satisfied with its operation, he signals the mechanic to pull the blocks out from the wheels. He is now ready to start.

At this point instruction in taxi-ing, or handling the plane on the ground, is commenced. The instructor taxies out, while the student watches how he uses the controls. In the first place, a landplane will not move with the engine idling. Hence it is necessary to open up the throttle to 1000 r.p.m. or so. At this speed, the propeller pulls it slowly along the ground. The stick is always held back of neutral, to prevent unintentional raising of the tail.

In order to turn, the rudder is used. To turn to the right, full right rudder is applied. The propeller blast on it then forces the tail to the left. It is not possible to turn sharply in this way, however. To accomplish a quick turn, the inner wing must be held by a mechanic, allowing the plane to pivot on it.

When, in the next hour, he starts taxi-ing himself, the student will find that the wind direction makes a great difference. A plane moving over the ground tends to swing like a weathervane and head into the wind. That is, if the wind is blowing against its right side, it will tend to turn toward the right until it is headed directly upwind. The brisker the wind, the more strongly this tendency is felt and the more left rudder must be carried to prevent it.

If the plane is now to be turned to the right, the wind will help and it can be swung easily. But the wind will oppose any turn to the left. To swing that way, the engine may have to be speeded up to throw a stronger blast from the propeller on to the rudder.

The effect of wind on a seaplane, which can swing freely, is even more marked. With the engine idling, it will always pivot like a weathervane and head into the wind. To turn out of the wind, the propeller blast on the rudder is used. But as soon as the engine is idled, the plane will swing back into the wind again.

Taxi-ing is not so easy as it looks. Instruction in it is important, and must never be neglected. The student should do all the taxi-ing during dual instruction. This is particularly true in seaplanes, which keep sliding through the water even with the engine idling. An inexpert student can do much damage by misjudging his course and running into another plane. Slow and careful is a rule that will save many an embarrassing situation.

A student once tried to turn sharply inside of another plane parked on the operating line. He thought he could make it by opening the throttle wider than usual and forcing the tail around quickly. This gave him a lot of speed. When he got well around and had too much momentum to stop, he saw that he probably would not make it. Unwisely,

however, he opened the throttle still farther in a last effort to swing sharply. Three seconds later there was a resounding crash as his wing wrecked the other plane.

When the plane arrives at the leeward end of the field, the instructor turns up into the wind. He now scans the ground ahead and the sky in every direction to see that there are no planes approaching which might interfere with a take-off. The student should do the same, for this is a vital safety precaution. In case any plane is seen which might possibly come close, the take-off must be delayed until this risk has passed.

Then, when sure that the path ahead will be clear, the instructor opens the throttle.

CHAPTER IX

THE FIRST LESSON

After the instructor has climbed to an altitude of a few hundred feet, he commences work. First he demonstrates the use of the controls, starting with the elevators. He pulls the stick back slightly, and in response the nose rises above the horizon. The stick is not held back, however. If it were, the nose would continue rising until the plane stalled. Instead, it is returned to neutral. As long as it is held here, the nose will stay at this angle. After a moment, the instructor pushes the stick slightly forward and the nose drops. When it is level with the horizon once more, he brings the stick back to neutral again.

He then shakes the stick and holds up one hand, the signal for the student to repeat the movement of the elevators. This he does, rather gingerly. But the nose responds just as it did for the instructor.

The latter now goes through the opposite movements, first dropping the nose below the horizon by pushing the stick forward momentarily, then holding it there a few seconds with the stick in neutral, and finally bringing it up to level once more with a backward movement of the stick. This maneuver the student likewise repeats. He now knows how to use the elevators.

The next thing is to try the ailerons. The instructor moves the stick to the right, and the plane starts tilting to the right. When the stick is brought back to neutral, the movement stops. The plane is now banked to the

right. To bring it back to straight flight, the stick is moved to the left momentarily until the wings are straight, then returned to neutral.

The student now banks several times, making similar movements. He then tries the same thing to the left. Now he is ready to use the ailerons.

Finally, the instructor pushes the rudder bar successively right and left. As the right side of it goes forward, the nose swerves to the right, and vice versa. The student repeats these movements, and thus learns the effect of the rudder.

He has now made all the basic control movements himself. The next step is to combine them into straight and level flight. He feels the stick shaken sidewise and sees both of the instructor's hands held up. He has control of the plane.

For a second or two nothing happens. Then perhaps the plane starts tilting to the left. At first the student does not observe this. When he sees it, the wing is already down five or six degrees. But, after a moment's thought, he remembers the proper thing to do. He moves the stick to the right. However, he is somewhat cautious about it. The situation is strange, and he does not want to do anything excessive. So he may not use enough opposite aileron, and the wing fails to come up.

About this time he suddenly realizes that the nose is pointing up toward the sky. Absorbed in the wing movement, he has failed to see its gradual rise. Startled, he pushes the stick forward. But in so doing he unconsciously moves his feet. As a result, the nose swerves sharply to the left. This causes the wing to drop farther. A sharp side blast of air strikes him in the face. The plane feels as if it were slipping out from under him. His confused

efforts with the stick and rudder bar seem to have no effect. He is losing control.

Then he feels a decisive movement of the ailerons and a sharp push on the rudder bar. Instantly, at a touch of the instructor's practiced hand, the plane is straightened out.

This process, with many variations, is repeated time

Courtesy of Loening Aeron. Eng. Corp.

A Cabin Amphibian on Land.
Loening C-2 eight-place amphibian biplane with 525 H.P. Cyclone engine.

after time. First one wing drops and then the other. The nose weaves around unsteadily, up and down, right and left. The student seems to himself to be forever chasing it. Nor can he judge just how much to move the controls. Sometimes he applies pressure to the ailerons and nothing happens. He increases it, and the wing bobs suddenly up.

Before he can stop it, the plane is tilted over the other way. And meanwhile he has forgotten the rudder. Again the instructor has to help him out.

But each time he tries it, he holds on a little longer. Soon he retains control for thirty seconds, then a minute, then two minutes. Things do not happen so unexpectedly. He sees the nose rising or the wings tilting before they have gotten very far. And he begins to get some idea of how much pressure to use on the controls. His movements become less jerky and uncertain. In response, the plane steadies down perceptibly.

It is now time to note the height of the nose in relation to the horizon. When the instructor indicates that it is in the proper position for level flight, the student will see some point on the engine, such as the top of Number One cylinder, in line with the horizon. He must then try to keep the nose in this position.

At this point two things which complicate control of the plane must be learned. In the first place, the ailerons are never used alone. The rudder must always be used with them. This is due to the fact that, when one aileron is depressed, it projects down into the wind stream and produces more air resistance than the other aileron, which is raised and still partly protected by the camber of the wing. The unequal drag thus set up tends to swerve the plane toward the side of the depressed aileron. So, when the stick is moved to the left to raise the right wing, the nose tries to swerve to the right. Left rudder must be used to prevent this. Whenever the ailerons are moved, the rudder is moved at the same time and in the same direction.

The other thing to be learned is that the average single-engined plane will not fly a straight course with the rudder centered. Instead, the nose will creep off toward the left.

This is due to propeller torque, the resistance of the air to the rotation of the propeller. The aerodynamical principle involved need not be explained here. But the result is that some right rudder must be carried all the time in order to fly straight. In learning how much to use, the student picks some object near the horizon. On this he tries to keep the nose steady. The rudder is considered as being in neutral when the right amount of pressure is being kept on it.

He may also find that constant pressure on the elevators, either up or down, is necessary. Perfect fore-and-aft balance in a plane is difficult to get except with an adjustable stabilizer, which most training planes do not have. Even then, any change in the engine revolutions affects the balance. But the pressure required is small, and will not bother the student. He will quickly learn to use the proper amount in order to keep the elevators in neutral.

After learning how to keep control in straight and level flight, the student tries gliding. As the instructor closes the throttle, he pushes the stick forward. When the instructor indicates the proper angle, he brings the stick back to neutral and tries to keep this angle. There are two ways of judging it. One is by the apparent angle of the fuselage with the ground and the horizon. The other is by the sound of the wings moving through the air. With the engine throttled down, any change in this sound can be easily heard. If it dies down perceptibly, the speed is getting low.

When the instructor reopens the throttle, the student pulls the stick back and raises the nose to level again. After a few tries, he will be able to glide fairly well.

The instructor may demonstrate a climb during this hour, though he probably will not have the student try it until

the second hour. But the latter can note the position of the nose in relation to the horizon. He should again pick some point on the engine, lower down this time, which will indicate a good climbing angle. Then, after he has learned to hold the plane in this position, he should always climb unless the instructor tells him to fly level.

A few suggestions for the beginning student. In the first place, do not grip the stick desperately. You will find yourself doing this if you are not careful, as it is a natural tendency. You are keyed up by your efforts to retain control, and this tension will be reflected in a tense grip unless you watch it. This is tiring, and results in quick fatigue. Instead, grasp the stick firmly, but no more tightly than necessary. The same thing applies to the rudder bar. Your feet should rest on it firmly, but your legs should not be tensed.

You will find the proper movements of the controls much smaller than you expect. In ordinary flying, the stick is seldom moved more than two or three inches. Any large movement would produce a violent lurch.

But, when you need to, move your controls positively and decisively. Vigorous work is sometimes required as the plane strikes a sharp gust. You will find the elevators the most sensitive of the three controls. Ordinarily a touch on these is sufficient. But the ailerons and rudder are less sensitive, and need to be used firmly at times.

Never look at the controls when you move them. This rule is very important. If you drop your eyes to the stick in order to use the ailerons, the nose may come up and a stall result before you know it. You must watch the plane. Learn to move the controls without looking at them.

Let go of the stick instantly if the instructor signals that he wants the controls. No matter what has happened to the plane, regardless of whether or not you have stalled it, he can recover control instantly as long as you do not interfere with him. If you want to hang on to something, grab the cowling.

Cases have occurred where students have become panic-

U. S. Navy Photo.

A Naval Amphibian at Sea.
Loening OL-8 amphibian biplane, with 425 H.P. Wasp engine.
The wheels are retracted into the hull.

stricken and clung to the stick. In 1923 an instructor was flying at 2000 feet altitude in a seaplane. He had a student who was finding difficulty with his turns, and was watching him carefully. He happened to be sitting with his hands grasping the collar of his leather flying jacket when the student accidentally stalled the plane. Naturally the nose

started to drop. But, since they had plenty of altitude, he waited for the student to recover.

Instead, for some unknown reason, the latter became panic-stricken and pulled the controls hard back. After which, his mind ceased to function. Now this particular type of plane, instead of a stick, had Deperdussin controls, a large wheel mounted on a yoke. Before he could move, the startled instructor found his hands pinned against his chest by the wheel. The student, hugging the other wheel in his cockpit, had "frozen" the controls. Of course the plane went into a tail spin.

Ordinarily the instructor would have been strong enough to take the controls by force. But, caught in this awkward position, he could not move his arms to get any leverage. There was only one thing he could do. The mouthpiece of the Gosport was over his mouth. He could try to talk the student out of it.

It would be useless to shout at the man. He was scared out of his wits already. The only chance was to reason it out with him. This he proceeded to do. His oration, under the circumstances, was a masterpiece.

"There really isn't anything to be alarmed about," he assured him. "Not a thing. We're absolutely all right. Only you're holding the controls a little far back. And also a little tightly. Now if you'll just kindly ease up on them a bit, we'll be out of this in three seconds. Just ease up a little."

The altimeter read 1000 feet. Twisting his head, he managed to catch a glimpse of the student's white face, jaws clenched and eyes staring through his goggles—still scared senseless, totally unconscious of his death grip on the controls. The situation was bad. But back to work the instructor went.

"Now there isn't a thing in the world to worry about. Nothing but a tail spin. Remember how we came out of it before? Nothing to be scared about, was there? Just ease up a bit and we'll get out of it again. Just a bit. That's it——"

He managed to slip one arm free as the pressure eased.

Courtesy of Fokker Aircraft Corp.

AN AMPHIBIAN CABIN MONOPLANE.
Fokker eight-place amphibian flying boat with 525 H.P. Hornet engine.

Another five seconds and he would have made it. But just then they ran out of altitude. When the crash boat arrived, the rescue crew found a crestfallen student and a very sour-looking instructor sitting on the wreck.

Devices have been patented which will keep the student from freezing the instructor's controls. In a plane equipped

with them, such a thing cannot occur. But in any case, all the student needs to do is to let go of the stick. The instructor will do the rest.

Learn to judge lateral balance by the nose instead of the wings. If you have to keep looking off to the side to tell whether the wings are level, the nose may rise, fall or swerve while you are doing it. After a little while you will learn to tell when the plane tilts by seeing the nose at an angle in relation to the horizon. Then you can take an occasional glance at the wings just to check up.

As soon as you can, try to think in terms of plane movements rather than of control movements. That is, when the nose rises, think of dropping it back to level rather than of pushing the stick forward. If the right wing is down, think of bringing it up rather than of moving the stick to the left. This is the way to develop the "feel of the air." Think of the plane and not of the stick.

Check up on your position in the cockpit. You have already done so on the ground. But be sure you are comfortable and can handle the controls without effort.

Remember to watch the instructor's signals and try to follow them. He will spot your mistakes at once and signal you to correct them.

Keep a piece of cloth handy to wipe your goggles. The engine may spit a little oil occasionally, and you need to keep them clean. If there should be wind leaks around the sides, get another pair when you come down.

Don't let "bumps" worry you. These are simply the jolts you feel as the plane goes through choppy air currents. They cannot possibly upset you so long as you keep plenty of speed. And don't look for "air pockets" or "holes in the air." These are myths of early days long since exploded. There could no more be a hole in the air than in the ocean.

Don't worry about airsickness. Even if you are susceptible to seasickness, you won't get airsick. You will have too many other things to think about.

Don't fly with your eyes glued to the nose of the plane. Watch it carefully. But take a glance around every few seconds. Look at your instruments. See if there are any other planes near you. Look at the ground to see where you are. You must keep alert in the air, and now is the time to start developing the habit.

Don't be surprised or startled when you lose control. The instructor expects you to do so at first. In fact, he would be astounded if you did not. He will always catch the plane before it can fall. Sometimes, when it is almost out of control, he may let you struggle with it. If so, do the best you can. But don't worry about his waiting too long. To him, recovering from a stall is not even exciting. It is pure routine.

And don't expect to learn to fly in an hour. If you can keep control for five minutes, you are doing finely.

CHAPTER X

TURNS

After fifteen or twenty minutes of straight flying, the student tries a turn. It will be remembered that, in order to turn, the plane must be banked. Only then will the rudder have any effect. But once in a bank, it will keep turning as long as the rudder is held on.

There are three distinct stages in a turn: (1) entering the turn; (2) in the turn; (3) coming out of the turn. The control movements in these stages are different, and the change from one to the other should be sharply marked.

To enter a right turn, the plane is banked to the right by moving the stick to the right. At the same time, considerable right rudder is applied. This pressure on the rudder is held as long as the bank is increasing.

When the proper bank of fifteen or twenty degrees has been reached, the wing is checked by bringing the stick back to neutral. At the same time the pressure on the rudder is eased, for less rudder is required to keep the plane turning than to start it. But this decreased pressure must be held throughout the turn. The ailerons are used as needed to keep a steady bank.

When it is time to straighten out, the bank is taken off by moving the stick to the left. At the same time, hard left or opposite rudder is applied. This is needed to keep the nose from swerving due to the unequal drag of the ailerons. When the wings are level again, both the stick

and rudder bar are brought back to neutral. The turn has been completed.

During training, all turns must be made with the nose level. Owing to the tilting of the plane, it stalls at a higher speed than in straight flight. Hence it is not safe for the student to try to climb in a turn. Before entering it, the nose must be dropped to level. It must then be kept there until the plane is straightened out.

In a plane whose propeller torque is appreciable, allowance must be made for this. If some right rudder is required in straight flight, a good deal will be needed in a right turn. But in a left turn the torque alone may be enough to keep the plane swinging. Little or no left rudder will then be required.

The student now encounters the problem of slips and skids. A turn is properly made only when, with a constant bank, the path of the plane is a perfect circle. For the beginner, however, this is not so easy. At first he will slip and skid completely out of control. But he must learn to recognize and avoid these two errors before he can fly safely. So the sooner he tackles the problem the better.

Perhaps slips and skids can best be described by an analogy. An airplane is designed to be pulled straight ahead by its propeller. But there is nothing to keep it from sliding sidewise through the air. If anything tends to push it to one side, it will readily yield and go that way.

Now imagine an automobile equipped with an airplane propeller running in the center of a greased track a hundred yards wide. The propeller will pull it straight ahead without any difficulty, and so long as no other force affects it, it will follow a straight course. But if anything pushes it sidewise, it will slide across the track.

Next imagine that the car must keep moving at 60 miles

an hour. At this rate it comes to a turn. The track is banked at exactly the right angle for the curve, and the driver follows the center line carefully. Under these circumstances the car will round the turn without difficulty.

But now suppose the track is only slightly banked while the curve is sharp. The driver, trying to follow it, twists

U. S. Navy Photo.

A turn in a naval training plane.

the steering wheel abruptly. Obviously the car will not turn as he intends. Instead it will skid, continuing on in a practically straight course toward the outside of the track. Since its wheels have been turned, it will be headed in the desired direction. But its real path will be at an angle to this direction. It will be crabbing along partially sidewise

to its actual line of motion. Naturally the friction caused by this sidewise movement will slow it down.

This case is exactly similar to one of the most common errors made by every student. He starts a turn and does

Courtesy of Alexander Aircraft Co.

A Left Bank in a Sport Biplane.
Alexander Eaglerock A-1 with 220 H.P. Whirlwind engine.

not bank enough. Then he uses the rudder vigorously and tries to force the plane around. Of course it does exactly what the car did. It skids toward the outside of the turn, sliding partially sidewise through the air. This sidewise

motion increases the air's resistance and slows the plane down. If the skid is bad, the speed will drop to the stalling point. Then, unless the stick is pushed forward right away, the plane will go into a spin.

Instructors find that, during the first few hours, much of their attention must be given to skidding. Whenever too

Courtesy of Curtiss Flying Service, Inc.

A Cabin Monoplane Turning.
Curtiss Robin in a left bank after taking off.

much rudder is used in proportion to the amount of bank, a skid results. This is the most likely cause of an accidental spin. But skidding is not difficult to recognize. And once a student has been thoroughly instructed in avoiding it, there is no danger of his losing control in this way.

To return to our automobile, suppose the track is steeply

banked but the curve is gradual. There is even a straight stretch which is banked. Obviously, as soon as the car hits the banked section, it will start sliding down toward the inside rail. On the straight stretch it will slip still faster. It will still be headed in the proper direction. But its actual path will be partially sidewise toward the low side.

This condition is exactly similar to the other most common error in turns, slipping. The student banks for a turn. But he fails to use enough rudder, and the plane does not swing fast enough for the amount of bank. Hence, like the automobile, it commences to slip sidewise and downward toward the inside of the turn. Perhaps he even forgets to keep the rudder on at all and lets the plane fly straight ahead for a few seconds. This makes it slip the faster.

Whenever insufficient rudder for the amount of bank is used, the plane will slip. However, there is no dangerous loss of speed for, though the plane is crabbing sidewise through the air, gravity is helping to pull it and keeps it moving fast enough. But altitude is lost, which is not desirable. And, if close to the ground, it would of course be possible to slip down until the lower wing hit.

The easiest way for the student to recognize slips and skids is by the wind flow. In either one, the sidewise movement of the plane through the air will cause an apparent side blast of wind on the face. If it is slipping, the blast will strike the inner cheek. While, if it is skidding, the blast will be felt on the outer cheek. Thus, in a right turn, wind on the right cheek would mean a slip and on the left cheek a skid. At first the beginner will find it hard to distinguish these side blasts from the eddies that swirl around the windshield. But they get in behind it quite distinctly, and will soon be readily felt.

To stop either of these errors, it is necessary only to correct the position of the rudder. In a slip, too little rudder has been used and hence it must be increased. In a skid, too much has been used and some must be taken off. It will be seen that in both cases the movement of the rudder bar is toward the side on which the blast of air is felt. When, in a right turn, a side blast on the right cheek indicates a slip, pushing the right foot forward will increase the rudder. On the other hand, when a side blast on the left cheek indicates a skid, pushing the left foot forward will decrease the rudder. Hence the rule, "Rudder into all side blasts of wind." As long as the student understands why he does this, it will be a safe rule to follow.

During the second hour, S-turns are commenced. These, as the name implies, are turns in which the plane is swung from one bank to the other without pausing in straight flight. They are useful in teaching the student to make his control movements definite and precise. During the rest of his dual instruction, he practices them on every flight.

When you start making turns, try to keep your bank constant. If it is ten degrees one minute and twenty the next, you will have trouble correcting your rudder for these fluctuations. When the instructor indicates that the bank is right, note where the inner wing is in relation to the horizon. Then try to keep it there in all turns.

Remember to make your control movements distinct for the three different stages. Use plenty of rudder going in. But don't forget to ease up on it the instant you check the wing. And don't be afraid of using too much opposite rudder coming out. You can step on it hard.

Don't forget to drop your nose to level and keep it there. Otherwise you may unexpectedly find yourself in a stall.

Don't be afraid to bank. If you get tilted over a little too far, that is nothing to get excited about. The plane is not going to fall. A little opposite aileron will bring the wing back where you want it. And it is safer to bank slightly too much than too little. In a flat bank you will tend to skid. Banking enough is the best way to avoid skidding.

A student in a seaplane course showed a disinclination to bank at low altitudes. Apparently he was nervous about getting the wing down close to the water. In taking off headed toward shore, where a prompt turn was necessary, he would bank only ten degrees or so and then try to skid around. Admonition failed to break him of the habit. So the instructor decided on drastic action. He had the student take off close to shore and fly straight toward it. When it was hardly 500 feet away, he signaled for a turn. At the same time he grabbed the stick and threw the plane over into a 45-degree bank. Then he held up both hands. The student made the turn. And the cure proved to be permanent. Finding that even a really steep bank was not difficult to handle, he thereafter banked properly.

Incidentally, if you ever should need to turn in a hurry, that is the way to do it. Never bank a little and try to skid around. Always bank her over and turn.

If you have unintentionally lost your bank, don't try to go on with the turn. You will probably skid. Straighten out and start over again.

A good turn cannot be made with the ailerons and rudder perfectly motionless. Just as in straight flight, air currents require constant use of them to keep the plane steady. The rudder especially must not be handled stiffly. Even if it is approximately correct, minor slips or skids will result, and the turn will be poor. Ease the rudder back and forth

lightly and feel out the turn. That is the way to develop sensitiveness to slips and skids.

Always look back before you go into a turn to be sure there is no other plane right behind you.

Don't expect to make good turns right away. Moderate slips and skids are nothing to worry about. They are not

Courtesy of American Aeronautical Corp.

AN AMPHIBIAN IN A TURN.
Savoia-Marchetti S-56 three-place amphibian flying boat with 90 H.P. Kinner engine.

dangerous, and all students have to learn them by experience. You can easily recognize them before they reach the dangerous stage.

Remember that there are only two ways you can spin out of a turn—holding the nose high and skidding violently. Watch those two things and you cannot lose control.

If a turn feels queer to you, *straighten out.* Pull the wing up hard with plenty of opposite aileron and rudder. At the same time ease the stick forward and pick up some extra speed. When the wings are level, neutralize everything. You can't go wrong if you straighten out.

Turns are not hard as long as you understand them and learn to feel your slips and skids. But they cannot be made mechanically. Don't move your controls by the count. Feel them out.

CHAPTER XI

TAKE-OFFS

At the beginning of the second hour, the student tries taking off. A take-off includes the handling of the plane from the time the throttle is opened until it is just above the surface in level flight. It is not especially difficult, and after an hour or two of practice there should be no trouble with it.

As we have already seen, the plane must pick up a certain minimum speed before the lift of its wings will raise it into the air. The purpose of the take-off is to gain this speed. When the throttle is first opened, the plane starts forward, rolling over the ground or, if it is a seaplane, skimming over the water. It must now be held on a course straight ahead. Under the pull of the engine it moves faster and faster until its wings will sustain it. Then it must be lifted into the air in such a way that it is under complete control from the instant it leaves the surface.

The first requirement is that the plane must take off headed directly into the wind. The reason for this will be clear from an example. Suppose the wind is blowing from west to east at 15 miles an hour. A plane which takes off at 40 miles an hour is standing on the ground headed west, or upwind. The velocity of the air flow around its wings is already 15 miles an hour. Only 25 miles an hour more is needed to lift it off the ground. So the pilot has only to open the throttle and gain a speed of 25 miles an hour

over the ground in order to have the 40-miles-an-hour air speed needed to take off. This he can do in a comparatively short distance.

Now imagine the situation if he were to attempt a take-off headed east, or downwind. The plane starts forward and attains a speed of 15 miles an hour over the ground. It is now traveling at the same rate as the wind. Therefore there is no air flow at all past its wings. So far as lift is concerned, it is in still air. In order to gain flying speed, its momentum must be increased by a full 40 miles an hour. That would mean a speed of 55 miles an hour over the ground. To gain this would require a long run. A severe strain would be imposed on the landing gear in hitting any roughness in the field. And the slightest mishap at such a speed might well be dangerous.

So, if a 15-mile wind means a difference of 30 miles an hour in required speed over the ground, it is easy to understand the rule about taking off upwind. It can be accomplished in about one-third of the space. There is no strain

A take-off.

on the plane from excessive speed over the ground. And there is no danger in case anything should go wrong. The wind-sock is the first thing to look at when getting ready to take off.

A landplane sits with its two wheels and tail skid resting on the ground. If it were to stay in this position, the dragging of the skid would keep it from picking up enough speed. So it is necessary to lift the tail off the ground. This is done by holding the stick fully forward when the throttle is opened. As soon as a little speed is gained, the

wind and the propeller blast, working together against the underside of the depressed elevators, will lift the tail.

The plane now rolls along on its wheels with the fuselage level. In this position it gains speed rapidly. As it does so, the stick is brought gradually back to neutral. As soon as enough speed is gained to leave the ground, the stick is pulled gently back. This raises the nose and lifts the wheels clear.

The stick, however, is at once allowed to return to neutral again. This permits the plane to fly along level gaining additional speed. A safe margin above the stalling point is essential before a climb is begun. But in four or five seconds, when sufficient speed is gained, the nose may be pulled up to a normal climbing angle.

The take-off of a seaplane is in general similar to that of a landplane. As it floats in the water, it can gain no great speed. So it must be maneuvered into a position called "on the step." The bottom of the float, instead of being straight, has an upward jog or step in it about two-thirds of the way back from the bow. The part of the bottom behind this step is some two or three inches higher than the forward part. When moving rapidly over the water, an air space is formed behind this step. Thus the weight of the plane rests entirely on the forward part. This aids it in leaving the surface.

To get the plane on the step, the stick is pulled all the way back when the throttle is first opened. As a little speed is gained, the bow of the float is forced up out of the water, just as the bow of a speed boat is raised. The stick is then pushed all the way forward. This lifts the tail, just as in a landplane. But the speed is now too great for the bow to be pushed down into the water again. Instead the entire plane is lifted until it is skimming along

over the surface like a surfboard. It is now on the step. In this position it quickly gains speed, and can be taken off in the same way as a landplane.

A few things to remember. Look at the wind-sock when you are ready to take off. You must head straight into the wind.

Of course, you will realize that the sock swings from the leeward side of the pole. So the end toward the pole is the windward end. A student once, however, got it into his head that the sock pointed like a finger in the direction in which planes were supposed to take off. He headed that way in a seaplane and tried to take off downwind. Then he wondered why he couldn't get on the step.

Look around before you give her the gun. Look everywhere—ahead, behind, above, to either side. Be sure no plane could come anywhere near you while you are taking off. If there is any plane which might do so, wait. Never run any risk of a collision.

Always give yourself plenty of room to take off. In a landplane, use the full length of the field. Even if you don't need it, you will feel more comfortable. Clearing the edge by a small margin is disconcerting for the beginner. And never head directly toward any buildings or tall trees. Taking off just over such obstacles is dangerous. In case the engine failed, you could not help hitting them. Pick a course which will take you over a clear space.

A pilot was one day taking off in a DeHaviland from a two-way field, a field whose width was sufficient only for east and west take-offs and landings. The wind was southwest, partly across the runway. However, he was familiar with crosswind take-offs, and had no difficulty getting into the air. Watching carefully ahead, he saw that the western

end of the field was far enough away so that he would clear it easily. But he looked out of the left side of the plane only, forgetting that the wind was tending to drift him to the right. Now it happened that, on this side, a large haystack had been piled up in an adjacent field just at the edge of the runway. And the wind had just enough of a southerly slant to drift him over to it. He was fifteen feet in the air, just settling himself for the flight, when his right wing met the top of the stack. Two seconds later he found himself hanging head downward in his cockpit, staring at the ground just below. The plane had landed on its back. Fortunately, however, both he and his passenger extricated themselves from the wreck with nothing worse than some painful bruises.

In a seaplane, with an offshore wind, don't hesitate to taxi a mile out into the bay. Your friends may think you conservative. But it is better to clear a hangar by three hundred feet than by thirty.

One day in 1918 an instructor, newly arrived at an air station, left the beach for his first instruction flight. There was an offshore wind, requiring a take-off toward shore. He had just completed his own training in a different and somewhat faster type. Apparently he did not appreciate the slowness with which the type he now had would climb. Anyway he taxied only a comparatively short distance out before turning around and opening the throttle. The plane got up on the step all right. But by the time it was ready to leave the water it was not far off shore. A group of students, waiting around the squadron office for planes, watched the pilot climb a few feet and then start to turn right. But the plane did not have power enough to climb while turning. And with the moderate bank he had he was getting around very slowly. In fact, as they presently

discovered, his turn was going to take him just about into the squadron office.

They jumped to their feet and stood watching the plane uncertainly. It was bearing swiftly down on them. And it was only a few feet up—just high enough to stick its float through the office roof. Somebody started edging

U. S. Navy Photo.

A take-off in a naval training plane.

away. That precipitated the retreat. In a moment they were all scuttling like rabbits for shelter.

But the pilot banked over farther and commenced turning faster. In a moment they saw that he was going to miss the office. Hastily they scrambled back again to see the excitement. He was headed for two planes on the beach now, and it looked as if he was going to wreck both of them as well as his own. But at the last moment he banked over steeply. This swung him clear of the beach.

But the plane did not have power enough to hold its altitude in a steep turn. It started slipping, while the students stared open-mouthed. Right opposite the office, hardly fifty feet away from them, the right wing tip touched the water. With a great splashing and crunching and ripping of fabric, the plane turned a cartwheel. When the spray subsided it was lying on its crumpled left wings, with the right wings pointing skyward. The instructor climbed out and, much embarrassed, waded ashore with his student.

Another thing to watch is your course. Don't let the plane weave from side to side. Before you open the throttle, pick something ahead to check the course by. Then keep the plane headed straight for it until you take off. If you should swing badly off the wind, cut the gun and start all over again.

Be sure you open the throttle wide. It is very embarrassing to get to the end of the field and then find that your throttle is half open and that you have too little speed to take off but too much to stop.

Never hold the stick forward too long. You might throw the plane on its nose. Ease it back as soon as the tail comes up.

In a seaplane, you may have to "rock" the plane to get it on the step. This consists in pulling the stick fully back and pushing it fully forward a number of times. In response, the plane pitches up and down like a rocking-chair. If the wind is light, this may be necessary to force it up on the step.

But don't forget to stop rocking when you do get up on the step. As soon as the plane gets a little speed, it will respond too vigorously to any such treatment. A student was once taking off on a check flight with the Chief Instructor to see if he was qualified to solo. His own instructor

had, of course, taught him to rock. But evidently he had a case of stage fright, for he forgot to do so. However, there was a good wind blowing, so the plane climbed up on the step without any help. In fifteen seconds it was skimming along over the water almost ready to take off.

But the student appeared to be quite unconscious of this fact. Evidently the magnitude of the occasion had completely disconcerted him. For, when his mind started to function again, his first thought was about rocking the plane. He had forgotten to do so. The deficiency must be remedied at once. This he proceeded to do by pulling the stick all the way back.

The startled instructor felt the plane lunge under him like a bucking bronco. It zoomed thirty feet up into the air and stalled dead. The student, now alive again and trying earnestly to carry out his instructions, did his best to go on with his rocking. If he had succeeded in getting the stick forward, the zoom would have ended with a dive into the bay. But the instructor managed to recapture his own stick just in time to quell this effort. By a fine exhibition of skill he kept the plane right side up until it dropped with a huge splash into the bay. Then he taxied in and explained sadly to the student that aviation was not for him.

Don't be in a hurry to take off. At first you will be, and the instructor will have to discourage your attempts to drag the plane off in a stall. But you will soon learn to wait until it picks up flying speed and then lift it off gently.

Don't forget to level off and pick up some speed before you climb. And then don't climb too steeply.

CHAPTER XII

LANDINGS

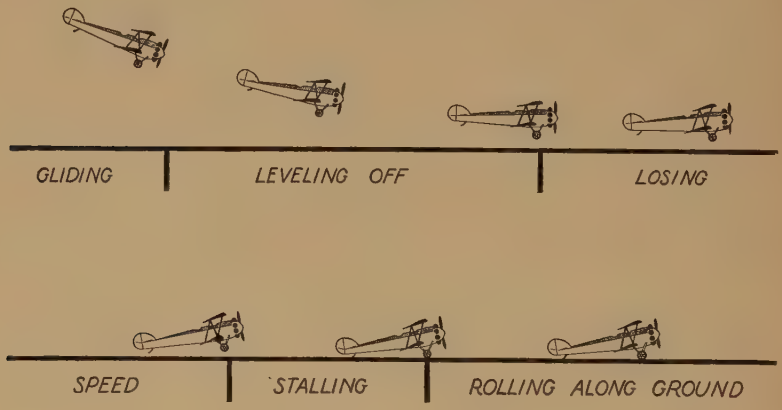
For the beginner, the hardest part of flying is getting down to earth again. He seldom has any trouble in leaving it. But when he comes to land, his real difficulties commence. So it is that an experienced instructor shapes all of his flights to give the student as much training in landings as possible.

As we have seen, when a plane is flying faster than its stalling speed, the lift of its wings sustains it. Now obviously, as long as this lift is holding it up, it cannot drop back on to the ground. So, in order to get down, it is necessary to lose lift. And to do this the plane must be allowed to slow down until it stalls. Only then can a landing be made.

But when a plane stalls, gravity causes it to drop with increasing rapidity. Moreover, it goes out of control, and the nose will quickly fall into the position of a dive. If the pilot simply brought it down somewhere near the earth and stalled it, it would plunge into the ground and wreck itself. So, to make a safe landing, the plane must be stalled in such a position that it will drop on to the ground gently and in the proper attitude.

A three-point landing from a height of one to two feet accomplishes this. The plane is brought down to this height in a glide and leveled off. It skims across the field parallel with the surface for several hundred feet. As it loses speed, the pilot gradually pulls the stick back. This

raises the nose and depresses the tail. The rate is such that the increasing climbing angle of the wings exactly offsets the decreasing speed and keeps the lift constant. Hence the plane neither rises nor falls. Finally it reaches the same attitude as when sitting on the ground, with nose high and tail down. In this position flying speed is lost at once and the stick can be pulled fully back, completing the stall. The plane drops. But this drop is so short that the shock absorbers on the landing gear take up all the



A three-point landing.

jar. And there is no time for the nose to fall. Instead, three points—the two wheels and the tail skid—hit the ground simultaneously and the plane rolls along in its normal taxi-ing attitude until its momentum is lost.

A seaplane is landed in exactly the same way as a landplane. It is brought down in a similar manner and stalled at a height of one to two feet. It then drops on to the water, hitting on the rear or heel of the float. This is called a full stall landing.

The explanation sounds simple. But its practical appli-

cation offers some unexpected difficulties. So the thing to do is to start on landings right away. The beginning of the second hour is not too soon.

Like take-offs, all landings must be made headed directly into the wind. A plane in a wind is like a boat in a stream. The latter not only moves through the water, but is also carried along by the current. If its speed is 10 miles an hour and the river is flowing at 5 miles an hour, it will make 15 miles an hour downstream. But headed upstream it will make only 5 miles an hour. So a plane flying 60 miles an hour down a 15-mile wind would be moving over the ground at 75 miles an hour. But headed into the wind it would be actually traveling at only 45 miles an hour.

To continue our analogy, suppose the boat could not slow down to less than 8 miles an hour and could not back. The pilot wants to make a landing at a dock. If he approaches it headed downstream, he cannot go slower than 8 miles an hour plus 5 miles, the strength of the current. Needless to say, he will not try to come alongside the dock at 13 miles an hour. But if he turns and heads upstream, the current will be subtracted from his speed. He can then approach the dock at 3 miles an hour and make a safe landing.

The case of the plane is exactly similar. It cannot slow down to less than 40 miles an hour in relation to the air. If the pilot tries to land headed down at 15-mile wind, his speed over the ground when he stalls will be 55 miles an hour. That might easily mean a wrecked plane. But if he turns and heads into the wind, the latter's velocity is subtracted from his speed and he lands at only 25 miles an hour. At this speed there is no danger of serious damage.

Of course a landing could be made crosswind. But then the plane would be moving sidewise over the ground at the

same speed as the wind, 15 miles an hour. When it hit, the wheels would skid across the surface at this speed and very likely collapse. The only safe rule in landing is to head straight into the wind. The wind-sock is as important to the aviator as the compass is to the seaman.

There are five stages in a landing: (1) gliding; (2) leveling off; (3) losing speed; (4) stalling; (5) rolling along

U. S. Navy photo.

Leveling off.

the ground. The student should learn to distinguish them as soon as possible. But the various elements involved are too complicated for him to try all at once. Instead he learns a few things at a time. Not until he has been taught all the different elements separately does he try to put them together into a complete landing.

In the first place, he does not try to handle the ailerons

and rudder at all during the first five hours. The instructor uses these as necessary. This enables him to concentrate on the elevators, the most important controls in landing.

The student has already learned how to put the plane into a glide by pushing the stick forward. Now particular attention must be given to getting the proper angle of glide. If it is too steep, excessive speed will be picked up. Then, when the plane is leveled off, it will shoot a long way across the field before it finally stalls. This is not dangerous, but it makes the landing more difficult and requires more room. On the other hand, if the glide is too flat, the speed will be too low. This may cause a stall. Therefore flat glides are dangerous and must be avoided. The instructor will demonstrate the best gliding angle.

The next step is to level off. The plane is not brought clear down to the ground in the glide and then suddenly pulled up level. Instead the glide is broken at a height of thirty feet or so by bringing the stick back momentarily. This pulls the nose up a little and decreases the gliding angle. The movement is repeated several times, thus gradually flattening the glide. Finally the plane is leveled off so that its course is parallel with the ground.

When the student first tries this he meets with little success. One time he will get the plane leveled off at ten feet. The next time the instructor has to pull the stick back sharply to keep from hitting the ground. But by the end of the hour he is usually able to level off within four feet of it.

At the beginning of the third hour the instructor makes several landings, while the student keeps his hand on the stick. He should try to observe as many things as possible. He can note how the ground looks when the plane is leveled off, how the nose rises as the stick is pulled back, how the

plane loses speed while keeping at a constant height, how the stick is finally pulled all the way back to complete the stall. Then he feels the plane drop. There is a slight jar as the wheels and tail skid hit, after which the plane rolls along over the ground.

Now the student tries it himself. And this is where his real difficulty starts. Keeping the plane at the right height while it loses speed is far from easy. If he does not pull the stick back fast enough, the wheels will hit before the plane is stalled. Then it will rebound into the air. But if he pulls the stick back too fast, the plane will climb up five or ten feet. If he were to stall it then, it would drop hard enough to smash the landing gear. Either error will spoil the landing.

On account of this necessity for accuracy, it is of the greatest importance for the student to go at it right. If he does not do so, he is likely to blunder along and make little progress. Here is where the instructor's experience counts most. If he is thoroughly familiar with instruction technique, he can direct the student's efforts so that he learns most quickly and easily.

Now, learning to fly is essentially a matter of trial and error. A man cannot step into a plane and land it right away. He must make mistakes first in order to learn. Suppose now that he comes down and tries to bring the stick back for a landing in one steady, continuous movement. He either pulls it back too slowly and hits the ground, or too rapidly and zooms up from it. After he has made each of these errors once or twice, he knows what will then happen if he makes them again. Hence repetition of them is valueless. The fact is that landing with anything like a slow, continuous movement of the stick is quite beyond the ability of the beginner. It is so far

beyond his ability that he learns practically nothing from attempting it.

How, then, should he go at it? According to our principle of trial and error, he should make mistakes; but not the same mistakes over and over again. He must vary his trials and make a variety of errors. So, instead of pulling the stick back in one sweep, he pulls it back in a series of

U. S. Navy Photo.

Stalling.

brief, tentative movements. He brings it back and lets it go forward, brings it back and lets it go forward, repeats this sequence eight or ten times. As he approaches the ground, this flattens his glide in a series of steps. Each step brings the plane nearer horizontal until it is parallel with the surface. Then his repeated, brief movements raise the nose in little jumps. Each time it comes up a little

higher. If he does it right, the height of the plane varies a little, but it neither hits the ground nor gets up too high. Finally it reaches the stalling point and he can hold the stick back, letting the plane drop.

Of course, the student does not at first complete this series of movements. He gets part way through it and then the plane hits or zooms. But the point is that he makes a variety of mistakes. And sooner or later, he is bound by the law of chance to get it right. When he does so, he sees just how a landing should be made and next time can try more effectively to repeat it. Also, he has more opportunity to correct his mistakes. No single movement is decisive. He may get a little too high. But he has already eased the stick forward again and stopped raising the nose, so he has a chance to recover while the error is still small.

This method, to read it, perhaps sounds more difficult than pulling the stick back with a single continuous sweep. But in actual practice it is much easier for the beginner. A good student takes to it naturally. In fact, he would be likely to work it out himself if he were not shown. It is much the best way to develop the feel of a landing.

Few completed landings are to be expected during the third hour, though two or three may be made during the latter part of the period. But, even with constant coaching from the instructor, it will be along in the fourth hour before the average student begins to get the feel of them. However, by the beginning of the fifth hour, he sees some light ahead. He has an idea of how a landing should be made. And, on the majority of his attempts, he gets the plane down without assistance, though not always so gracefully as might be.

At the beginning of the sixth hour, the ailerons and

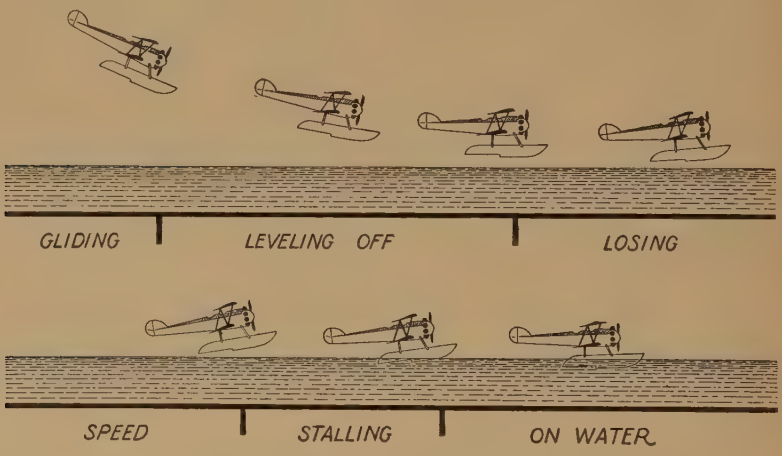
rudder are turned over to him. This complicates matters. Accustomed to think only of the elevators, he finds the plane displaying an unaccountable tendency to tip over sidewise just as he stalls it. This bothers him at first. But presently he discovers that it is due largely to unconscious movements of his feet. Without realizing it, he has been moving the rudder bar slightly. The resultant swerving of the nose with the plane nearly stalled has the additional effect of tilting it sidewise. As soon as he learns to keep the rudder steady, or to use opposite rudder when a wing starts to drop, he has no more trouble.

He must now cut down the excessive motion of the elevators. His tentative, repeated movements of the stick have served their purpose in enabling him to get the feel of the landing. But now he wants to develop a higher degree of precision, and with this they would interfere. So he tries to reduce steadily the amount of forward and backward movement of the stick. It is not likely that he can eliminate all of it yet. But by the end of his dual instruction his landings should be fairly smooth.

At the start of the sixth hour use of the throttle is also begun. Heretofore the instructor has handled it. But now the student takes charge of it. As soon as he has climbed as high as he is going to, he must throttle down. Running the engine at full speed all the time causes unnecessary wear and tear on it. When flying level, it should always be slowed down to cruising speed. That is, if its maximum speed is 1800 r.p.m., it should be throttled to approximately 1600 r.p.m.

When coming in to the field, the throttle must be used to make an approach. If it were closed fully and kept closed as soon as the plane entered the glide, the latter might end up anywhere in the field; or it might miss the

field altogether. So instead, the throttle is only partially closed, to perhaps 1200 r.p.m. Then it can be varied as necessary. If the student sees that he is a little low, he can open the throttle to 1400 r.p.m., pull the nose up somewhat, and lengthen the glide without losing any speed. On the other hand, if he is high he can cut the throttle to 900 or 1000 r.p.m. and glide more steeply. By using it in this way, he can make an approach and land fairly close to any spot the instructor designates.



A full stall landing.

When practicing landings, the instructor does not usually stop after each one. Instead, he opens the throttle again as soon as the plane is on the ground. The student must be ready for this. As soon as he hears the engine again, he must return the stick to neutral and proceed with the take-off.

To recover from a bad landing, the throttle is opened wide. If the plane hits the ground and rebounds, or if it is leveled off dangerously high, the only way to save it

from damage is to continue flight. If it were allowed to stall and drop from a height of five feet or more, the landing gear would probably be carried away. At first the instructor opens the throttle when necessary. But the student must learn to do this so that, if he makes a bad landing on a solo flight, he can recover from it.

During the second five hours of his dual instruction, the student gets acquainted with forced landings. He is flying along smoothly when suddenly the engine slows down. The instructor has pulled the throttle back and is holding it. So far as the student is concerned, the engine is dead. Gravity is reaching for him. And it is up to him to do something about it.

There is now just one vital thing he must remember—*keep flying speed.* The plane is going to come down. If he keeps his speed, he can bring it down under control. But if he does not, it is coming down anyway. And its way of coming down will be in a tail spin. At least, it would be if the instructor were not there. If he has to take the controls, it means that, theoretically, that particular landing was a crash.

To keep flying speed, the nose has got to be pushed over into a glide right away. And it has got to be kept there. That is the first condition of a safe landing. Never, under any conceivable circumstances, must it be pulled up. The plane is not a balloon, and it simply will not float. It must keep coasting downhill. The hill can be long and straight, or it can be twisted around into a spiral. It may be made as steep as need be. But it can never be flattened. Smashing into a brick wall is safer than trying to float over it by flattening the glide.

The instructor may close the throttle anywhere at all. If the field is big, or if flying a seaplane, he will frequently

do so just after the take-off, anywhere from two to ten feet up. If not higher than three feet, the student can consider the plane as leveled off and can go ahead and land. If higher than that, it must be allowed to settle to the right height before being stalled. It is on such landings that he appreciates the importance of flying level for a few seconds after taking off. This gives him speed enough to retain control when the throttle is closed.

In case the throttle is closed as the plane is leaving the field after a take-off, there is just one thing to do—*go straight ahead.* This rule is imperative. It is one of the most vital things the student must learn. No matter what is ahead, go on into it. For it is a physical impossibility to spiral back to the field. With the plane gliding fast enough for safety, it takes only so many seconds to reach the ground. And it simply is impossible to turn it in that time. There is no need to try it, because too many men have already demonstrated conclusively that the thing cannot be done.

About three years ago a group of instructors were watching solo students practicing landings. One man had landed, taken off again, and climbed to about 200 feet altitude. His plane was just about over the edge of the field, headed away from it, when some one saw the propeller slow down.

"Forced landing," he called. All eyes turned that way, for, needless to say, such a landing takes precedence over everything else. Ahead of the plane were underbrush and low, scattering pines. A landing would certainly tear up the wing fabric. And it would probably throw the plane over on its nose. But this would not cause any great amount of damage. And the student need expect nothing more than a shaking-up.

He had nosed down promptly enough. But now he

started to turn toward the right. The instructors watched him somewhat doubtfully. Still, by turning a little, he could reach clearer ground. He had altitude enough for that. And as long as he did not try to turn very far, he was all right.

But he kept on coming around in a slow, shallow spiral. They began to feel the beginnings of apprehension. The ground ahead of him now was as clear as any he could reach. Why didn't he straighten out and get set for the landing? He had to go into it anyway. There was no use turning any farther. But still he held the plane in that flat spiral.

"He isn't trying to make the field, is he?" somebody asked.

There was a pause. Nobody wanted to admit it. But finally there came a reluctant answer.

"Looks as if he was."

They could see his glide growing flatter and flatter. Already his air speed must be fluttering around the stalling point. Apparently he had forgotten all about it. His mind fixed on the field, he was evidently oblivious to everything but his desire to reach it. But nobody on earth could have gotten that plane turned around. The thing was an impossibility. And when an aviator attempts the impossible, there is just one answer.

The lookout in the watch tower reached for the alarm siren. The ambulance driver stepped on his starter. The Medical Officer swung up beside him. The crew of the emergency truck jumped aboard. Everybody else on the field stood and watched.

The plane was about fifty feet up when it finally ran out of flying speed. Naturally it went into a spin and crashed.

This type of plane had an all-metal fuselage and, being a training craft, was slow. From the point of view of personal safety, it stood the shock well. Neither cockpit was crumpled up. The student was dazed, but his actual injuries consisted of a black eye and a bruised shoulder. However, instead of being brought in for minor overhaul, the plane was carted off to the junk pile.

Crashes such as this are rare when strict training is given. The experienced instructor goes through repeated drills in engine failure. When the throttle is closed, a properly trained and competent student never dreams of trying to turn back. It is instinctive with him to nose over instantly and keep going.

A few days after this particular crash, another solo student was taking off from the same field. Just as he passed over its edge, his engine dropped to 1200 revolutions, insufficient to keep him in the air. Ahead of him was the same kind of ground. But he did not even glance backward. His nose went down and he kept going straight ahead.

Taking advantage of the feeble pull still left in his engine, he eased around a clump of small trees and then dropped to the ground in a fairly clear space. Closing the throttle, he leveled off and pulled the stick back for a landing. When the plane came to a stop, there was a sapling sticking up into the fuselage. But otherwise it was undamaged. It had not even gone over on its nose.

Of course, no actual landings are ever made when the throttle is closed in such a position. It is not necessary to risk the plane in any way. Once the student has been taught to start a forced landing properly, it can be assumed that, in case of real engine failure on a solo flight, he would finish it properly. So, before there is any danger of hitting an obstacle, the instructor reopens the throttle and goes on.

When the throttle is closed at higher altitudes, 500 feet or above, there is an opportunity to pick a landing place. The plane can then be spiraled in an attempt to land there. (Spirals are described in Chapter XIV.) A safe landing is of course desirable. So whenever he is high enough, the student is supposed to try it. At this stage of training, however, no great degree of accuracy is expected. Pre-

U. S. Navy photo.

Stalling in a seaplane.

cision requires a knowledge of certain maneuvers not taught until the latter part of the course. So the student is not encouraged to attempt too much accuracy. He should always turn into the wind. But he must bank moderately and keep plenty of speed. Then, if the plane ends up in the field, he can land there. If it does not, he must put it down wherever it happens to be. But so long as he has

taken care to keep his flying speed all the way to the ground, he is safe.

There is no more important part of dual instruction than these emergency drills. No matter how competent a student is, he cannot solo safely until he has been through them. Like fire or collision drills at sea, they are absolutely necessary to safeguard life and limb. For every man makes serious mistakes on his first few emergencies. It is simply human nature to do so. If these mistakes are not to wreck the plane, they must be made while the instructor is present to correct them. The latter can sit there ready while the student does his best. Then at the last second he can open the throttle, take the stick and pull the plane clear. And he can repeat this procedure over and over again until the student has made all his mistakes and knows just what to look out for. This kind of instruction provides all the benefits of experience in forced landings with none of the risks. Then, in case the engine really stops on a solo flight, the student is not helpless. He knows what to do because he has been there before.

CHAPTER XIII

SOME SUGGESTIONS ON LANDINGS

Since the first essential of a good landing is that it be made into the wind, you must know the wind direction. And, since the instructor may cut the gun at any time, you must know it all the time. The wind usually keeps blowing in the same direction as when you took off. But you cannot assume this. It might happen to change. If you should fail to notice this and come in to land the same way as before, there is no telling what might result. Therefore you must watch the wind.

Incidentally, smoke is an excellent wind indication. You can see it from the air better than anything else. If there is a smokestack or a bonfire anywhere in the vicinity, get into the habit of glancing at the smoke from it.

Look out for other planes. Before you nose over into a glide, be sure there is nobody who either is in your way or might get into your way. Look ahead and to either side. And if there is any plane on the ground which might taxi in front of you, or might try to take off ahead of you, be careful. As a landing plane, you have the right of way. But if anybody either will not or cannot give it to you, it won't do you much good to try to take it.

One day an instructor was taxi-ing out into a field getting ready to turn around and take off into the wind. While he was glancing off toward one side, he felt his student cut the gun. Looking up, he was startled to see another plane dead ahead coming straight for them. The other man had

landed, apparently without seeing them, and then opened the throttle to take off again.

There was nothing they could do. He was hardly a hundred yards away. They had no time to turn out of his path. There was not even time to unbuckle their parachute straps and get clear of their plane. They were safest in the shelter of the cockpits. The instructor saw the other plane leave the ground headed straight for them. Then he ducked his head under the cowling and waited for the crash.

However, it did not come. He had a glimpse of wheels flashing past just over his top wing. They cleared it. But he was sure it was by no more than six inches.

He found out afterward that there was another instructor in the other plane. The latter told him privately that he never saw him until he was right over him. However, such things happen very rarely among experienced pilots and well-instructed students.

On another occasion, when the old Jennies were still being used, an instructor was coming in for a landing with one of his students. The latter was well along in the course, with over thirty hours' solo. As they approached, the instructor saw the shadow of another plane on the ground. It was apparently on a converging course with them, directly off their left wing. But the forward cockpit of a Jenny is blind, and in spite of much neck-twisting he could not see the plane itself.

If it was well above them, everything was all right. And if it was not, his student should be turning away. Since the latter showed no sign of banking, the instructor was warranted in assuming that the other man was high enough to be clear of them. However, his shadow kept getting darker and clearer. He couldn't be much higher. And the shadow was getting very close. Finally, at an altitude of

U. S. Navy Photo.

An approach over trees.

about twenty feet, the instructor decided to have a look for himself. He grabbed the stick and swung sharply to the right. It was just as well he did. The other plane was hardly twenty feet above them, barely enough to be hidden from him by the top wing. And he had picked the same spot for a landing. The two planes would have tangled wings just as they landed. In the other plane was a solo student belonging to the same instructor. The latter, shortly thereafter, got both of his students together for some remarks on the subject of looking around in the air. On the conclusion of these, they were quite ready to admit that, for aviators, frequent exercise of the muscles of the neck is the surest guarantee of a ripe old age.

Don't spill the plane "over the hump" into a glide when the instructor cuts the gun. The stick must, of course, be pushed forward instantly. But instantly is to be interpreted with a certain moderation. It means right away. But it does not mean with a bang. There is no need to slam it forward. The plane is not going to drop like a rock when the gun is cut. Ease it forward promptly but not violently, and go into the glide smoothly.

One young instructor, whose experience was less broad than it later became, had developed a trustful attitude toward students. He was checking a man who was supposed to be pretty good. As they were leaving the field at about 100 feet altitude, he casually cut the gun, just to be sure the student knew what to do. He did. He slammed the stick forward so sharply that it almost lifted the instructor out of his seat. The ground fairly jumped up at them.

Fortunately, the student's lapse was only momentary. He pulled back in time to clear everything by a safe margin. But the instructor's frantic grab, which missed his own stick, resulted in a fundamental change in his attitude.

He still trusts students. That is, he trusts that they will do the right thing. But he takes no chances on it. Whenever he cuts the gun suddenly now, he has a good grip on the stick and his feet are braced on the rudder bar, ready to subdue any excess of enthusiasm.

When you cut the gun yourself, as you will during the latter part of dual work, don't handle the throttle as if it were red-hot. There is no need to make a stab at it and jerk it off, as some students want to do. Take your time and ease it back. At the same time ease the stick forward and put the ship over the hump gently.

Look out for flat glides. They are dangerous. You can glide as steeply as you want (though your instructor won't like it very well if you persist in diving at the ground). But keep out of "graveyard glides" with the plane fluttering on the verge of a stall.

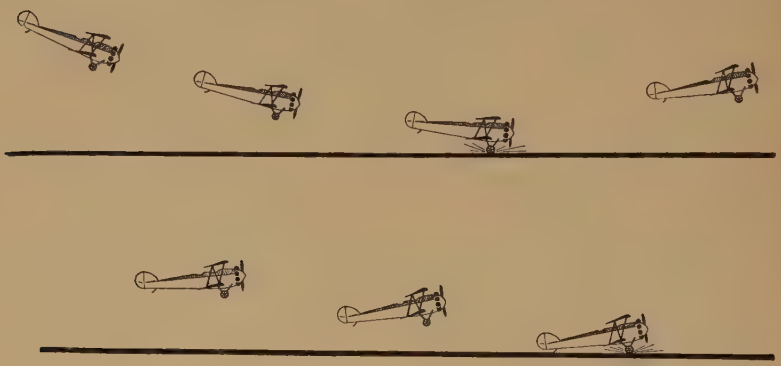
You must look in the proper direction when landing. Coming down in a glide, look over the top of the engine. When you level off, shift your line of vision so that it passes alongside the engine—either side—and meets the ground two or three hundred feet ahead of the plane. You then judge your height by the small angle your line of vision makes with the surface. Of course you do not estimate it accurately at first. But this is the way you must go at it.

Never, under any circumstances, look down at the ground directly in front of your lower wing. It is going by so fast that you would have no idea how close your wheels were to it. They might be four inches or four feet. You couldn't tell the difference. One student spent five hours uselessly before his instructor, somewhat short of experience, discovered that he was looking downward. You must look ahead past the side of your engine.

If you will realize the importance of moving your con-

trols in learning to land, half the battle is won. Landing with a slow, precise movement of the stick is, at this stage of training, a sheer physical impossibility. The only way you can get anywhere at all is by trial and error. If you try to bring the stick back slowly, you either fail to pull it back enough and hit the ground, or you pull it back too far and zoom. After you have made these mistakes, there is no sense in repeating them over and over again.

You must move the stick in order to learn. Pull it back



A Bad Landing.
The plane hits the ground, rebounds into the air, stalls, and drops on to the ground heavily.

and push it forward, pull it back and push it forward—quick, brief, tentative movements repeated constantly. Each time the stick comes a little farther back, raising the nose a little at a time. Of course you do not get it right at first. You hit the ground or zoom part way through the landing. But you are making a variety of mistakes, feeling the plane out, getting the hang of it. And every little while you get farther along through a landing than you ever got before, until finally you go all the way through with one.

Once you have actually landed a plane without help,

even if it was a rather crude effort, you have something to go on. You know you can do it. Now all you have to do is to learn to do it better. And as you progress, you will develop your feel of a landing more and more. You are aware of the stall approaching and can tell how close you are to it. You feel the plane start to drop and learn to judge instinctively the instant when you can pull the stick all the way back. Once you can feel out your landings accurately, your biggest troubles are over. Then you can start eliminating the excess motion of the elevators and developing precision.

Landing by repeated, tentative movements like this may sound difficult. But actual practice shows that it is in line with the normal tendency of students. A good student, even if not directed to do this, will ordinarily discover the idea himself. An instance illustrates the difference in results obtained by different methods. Since the final objective is to teach the student to land smoothly, some instructors have in the past tried to approach this objective directly. Accordingly, they have discouraged the attempts of their students to move the elevators tentatively and instead have insisted that they try to land with a slow backward sweep of the stick. One man, under this kind of instruction, spent five hours in the air without making the semblance of a landing. One time he would hit the water and the next he would level off twenty feet up. Other operations required a change in instructors, and the student was assigned to a pilot with several years' training experience. The latter at once had him change his procedure to conform with the more efficient technique. Inside of two hours he was making fairly good landings. On completion of his dual instruction he soloed safely.

As soon as you have learned to land using the elevators

freely, commence cutting down the excess motion right away. Remember that such a landing is not a good landing. It is simply an instruction landing, designed to teach you in the quickest, most effective manner. You must smooth out your handling of the stick before you can develop precision. This you can easily do by the end of ten hours.

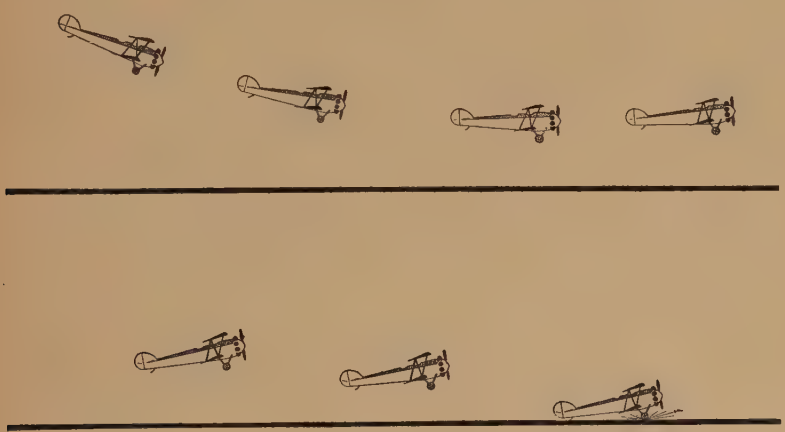
Don't get discouraged if you cannot land right away. Many students have a lot of trouble with landings. Some go along for six, seven or even eight hours before they make much progress. One student went nine and a half hours without making a single good landing. His instructor had given him up as hopeless. Then the idea seemed to come to him all at once. He had to take three extra hours before he was ready to solo. But he later became a very good pilot. However, his case was exceptional. Not more than eight hours should be needed to make reasonably good landings.

Incidentally, if you should have trouble with landings, your instructor will go on working with you just as if you were getting them perfectly. That is, he will if you have selected a responsible school manned by experienced instructors. Any impatience over a student's errors indicates a lack of understanding of the fundamental principles of training. He cannot help making mistakes. It is the process by which he learns. If he has any potential ability, a show of irritation will handicap him needlessly. If he has not, it is not his fault and irritation over it is foolish.

Patience is not a spectacular virtue, nor one commonly associated with flying. But it is a vital qualification for an instructor. The constant repetition of errors by students becomes monotonous. Unless a pilot is fitted for training

work, this will wear on him. Some exceptionally good aviators do not take to instructing. But if you have a good instructor, you need not expect him to show the slightest sign of impatience no matter how wild your attempts to land may be. Correcting them is part of his job.

Don't be fooled by "hot" landings. You may make a landing that you think is beautiful. But the instructor shakes his head. You have let your wheels go on before



A Bad Landing.
The plane is leveled off too high, stalls, and drops onto the ground heavily.

you got the tail down. The plane was not fully stalled when they touched. The ground happened to be smooth in that particular spot, and you got away with it. But if the wheels had hit a little rut or ridge, you would have gone bounding back into the air. The same thing holds good with a seaplane. On smooth water, you can make a very easy landing by putting the plane on hot. But try it in choppy water and you will find yourself soaring up into the air again. You must get your tail down. You

cannot be sure that the plane will stick unless you have it fully stalled.

If a wing starts to drop just before you stall, rudder is the thing you need. Jam on hard opposite rudder and you can stop it.

On every landing, be ready to give her the gun if you need it. When you make a bad landing, the engine is the one thing that will save you. If you were to let the plane drop on hard, something would very likely carry away. Then it would tip over on to its nose. So, if you hit too soon and bounce back into the air, or if you find yourself losing speed five or six feet up, don't hesitate. Give her the gun. And give it to her full—get the throttle wide open.

Don't let go of everything when you touch the ground in a good landing. The plane is still rolling at thirty miles an hour or so. You must hold it on a straight course until it stops.

If the plane tries to ground-loop, to swerve to one side, stop it with a shot of the gun, a brief burst of the engine. Otherwise it may tip sidewise enough to scrape one wing along the ground. But a brief blast from the propeller, hitting the rudder, will check any tendency to swerve.

In seaplanes, be careful of glassy water. It looks like a mirror as you glide down to it. And since there is no frame around it, you cannot judge your height. Pilots have glided right into glassy water, not realizing that they were near it.

The only safe way to land is by a power stall landing. In this, the plane is brought down and leveled off near the water, but not close enough to run any risk of hitting it. The engine is kept running at 1000 to 1200 r.p.m. and the nose is held level. In this attitude the plane will settle

slowly. The pilot does not need to estimate its height at all. He merely waits until he feels the float hit, which it will do quite easily. Then he cuts the gun and lets it settle into the water.

Finally, during your dual instruction you must get ready for motor trouble. Get the fundamental requirements of a forced landing firmly fixed in your mind. You don't need the finer points now. Those will come later. But you must know the things that make the difference between a safe landing and a crash. There is little chance that you will meet real engine failure right away. But it is not impossible. Therefore you must be ready for it. And to be ready for it, you must get ready now.

The best way to get ready is to think of two words—flying speed. Every time the instructor cuts the gun, say those words over to yourself. And if the engine ever should stop on you during a solo flight, keep on saying them. Repeat them over and over again all the way down to the ground. Never mind what is ahead of you. Just keep coming down. As long as you keep your speed, you can't go wrong. Nobody ever fell out of the air from too much speed. And if you don't fall, you can't kill yourself. Get down to the ground still under control and you are all right. You may hit something and crack up. But, as the old saying goes, "It's a good landing if you can walk away from it."

CHAPTER XIV

SPIRALS, STALLS AND SPINS

A SPIRAL is a turn in a glide, and is simply a combination of these two maneuvers. The plane is nosed over into a glide. Then it is banked with the ailerons and turned with the rudder just as in an ordinary turn. The same three stages can be distinguished—entering the spiral, in the spiral, and coming out of the spiral. And the relative movements of ailerons and rudder are exactly the same in these as in the corresponding stages of a turn.

The requirements of speed are the same as in a straight glide. The nose must be kept down far enough to maintain a safe margin above the stalling point. This is the first essential in a spiral.

The plane is usually banked more than in a turn. Thirty degrees is a good bank for a student. Also, the rudder must be used more fully since, with the engine throttled down, the lack of the propeller blast on it makes it somewhat less effective.

Spirals are usually made to landings. Training in them is begun during the sixth hour. After some practice, the student should be able to make a quarter-spiral, or spiral of 90 degrees, from an altitude of 250 feet. And he should be able to make a half-spiral, or spiral of 180 degrees, from 500 feet.

The most common errors in spirals are the same two which we found in turns—skidding and slipping. And they result from exactly the same causes. Too much rudder in propor-

tion to the bank will cause a skid, while too little rudder will cause a slip. So, if the student is making good turns, he should have no trouble with his spirals.

A stall, as we have seen, is the condition of a plane which has lost flying speed. It is very important for the student to become familiar with this condition from actual experience. So the instructor takes him up for a thorough workout in the processes of loss and recovery of control. This is ordinarily done during the ninth hour. It should never be left to the tenth, as this is just before solo and the student will then need to concentrate his entire attention on flying carefully and smoothly.

To start off, the instructor climbs to an altitude of 3000 feet or more. There, under his direction, the student pulls the stick gradually back. The nose rises, past the climbing angle and up to an angle of 15 or 20 degrees. The plane slows down. The student can feel the controls becoming logy as it squashes through the air. Finally, in spite of the elevators, the nose will drop. This means that the plane has been stalled and is starting to fall.

The nose continues to drop until it is down below level. But there is no precipitate dive earthward. The plane simply squashes downward in approximately its normal flying attitude, its forward speed only slightly below the stalling rate and its downward momentum not great. But it is under poor control, and might fall off at any instant.

As soon as the nose has dropped, the student eases the stick forward. The plane immediately picks up speed and goes into a normal glide. In this, complete control is regained at once. The student repeats this maneuver several times. He also tries pulling the stick back in a glide. In the latter case the same thing occurs. As the glide is flattened the speed decreases. Finally, in spite of the elevators,

the nose drops, indicating a stall. But as soon as the stick is allowed to go forward, speed is picked up and control regained. The student thus learns that a stall is nothing to worry about. There is plenty of warning as the controls become logy and the plane squashes along. And, so long as he has altitude enough, he can recover promptly.

However, there is little chance of an accidental stall in straight flight. It would be much more likely to occur in a turn if the student were not instructed in avoiding it. Hence the next thing is to stall the plane while turning. The student banks and, at the instructor's signal, pulls the stick gradually back. The nose rises again. But this time it does not rise so high before the symptoms of a stall are felt. This is due to the fact that more speed is required in a turn than in straight flight, and hence the stalling point is higher.

The controls again become logy and the plane starts to squash through the air. But this time, with the wing already part way down in a bank, the plane will start to fall off toward that side. That is, if in a right turn, the right wing will suddenly start to drop into a steep bank and the nose will go down sharply. As this occurs, the student pushes the stick forward and at the same time applies hard opposite aileron and opposite rudder. He also throttles down. Flying speed is picked up at once, and the plane is straightened out into a normal glide.

The next lesson is in stalling the plane by skidding. This is somewhat more difficult for the student to recognize, as it occurs with the nose level or even below the horizon. He starts a turn and then applies full rudder. This, as explained in Chapter X, swerves the nose and sends the plane skidding sidewise through the air. The increased resistance of the latter quickly slows it down. In order to hold the

nose level, the student will find that he has to hold the stick constantly farther back. Finally, in spite of the raised elevators, the nose will drop. The plane has stalled in level flight with the engine running at full speed, due solely to the violent skid resulting from the use of too much rudder.

U. S. Navy Photo.

AN OBSERVATION PLANE.
Vought Corsair two-seater with 425 H.P. Wasp engine.

As the nose goes down, the inner wing will also drop. But as soon as the stick is pushed forward and opposite rudder applied, control will be recovered at once.

The student stalls the plane repeatedly, by both climbing and skidding. Thus he learns to recognize these two errors promptly and unfailingly. And he learns that, the instant

he pushes the stick forward, he will regain control. With this training, there is almost no chance that he will stall accidentally in a turn. And even if he should, he would instinctively do the right thing and recover.

Finally, the student tries putting the plane into a tail spin. He stalls it and then, when it falls off, pulls the stick all the way back. The nose at once drops to a steep angle, about 50 or 60 degrees, and the plane commences to fall. At the same time it starts rotating rapidly on a vertical axis. The tail, which is pointing upward, whips around in circles. To the student, looking downward, it appears as if the earth were a great spinning pinwheel.

A plane in a spin is stalled. That is, its rate of falling is less than its stalling speed, on account of the large angle of attack at which its wings are meeting the air. But it can continue to spin only so long as it remains stalled. If it is allowed to gain flying speed, it will stop spinning. Hence, in order to recover control, it is necessary only to let the stick go forward. Once the elevators are neutralized, the plane cannot go on spinning. It must emerge in a normal dive, in which a safe margin of speed is immediately picked up. The nose can then be pulled up to level flight merely by bringing the stick back lightly.

The student spins several times. He stalls the plane, closing the throttle as he does so, and then throws it into the spin. On signal from the instructor, he eases the stick forward to neutral. The plane at once stops spinning. After letting it dive for a moment to gain speed, he draws the stick gently back. As soon as the nose is up level again, he reopens the throttle.

A spin is just as simple as that. The plane will stop spinning by itself if the controls are merely neutralized. It can go on spinning only as long as it is held in the spin.

Why, then, do we read about tail spins which end in crashes? For certainly planes do fall in this manner. Every so often the newspapers carry an account of a plane which went into a spin and ended up a wreck on the ground. And not infrequently they go on to say that the pilot was unable to recover control. There appears to be a discrepancy here.

But there is in fact no discrepancy. For, in any properly designed plane, there is never any mystery about the cause of a spin. It happened purely and solely because the pilot lost his flying speed. And there never was a spin in such a plane which the pilot was unable to stop. If it went on spinning, it did so because he held it in the spin.

Why should a pilot hold his plane in a spin? He does not do it intentionally, of course. He thinks he is trying to come out of it. But he simply forgets the fundamental principles involved. And hence he does exactly the wrong thing.

Here is a typical way in which an accidental spin occurs. A student starts a right turn. But he fails to watch his wing carefully, and loses most of his bank. Naturally the plane turns slowly. Anxious to get around faster, he puts on more right rudder. This starts the plane skidding. But it does not speed up the turn. Hence, in some uncertainty, he tries a little more rudder. In a few moments the plane is skidding badly and losing speed. It approaches the stalling point and, naturally, the nose starts to drop.

The student, however, does not realize that he is stalling. Seeing the nose going down, he instinctively pulls the stick back with the intention of raising it. If he had flying speed, this would be the right thing to do. But now it is exactly the wrong thing. For it of course completes the stall. Astounded, he sees the nose drop sharply. In confusion he continues to hold the stick back, trying vainly to

bring the nose up again. Instead, he finds the earth apparently whirling around beneath him. This completes his bewilderment, and he spends the rest of his downward journey hugging the stick to his stomach, doing the one thing which absolutely prevents his regaining control. There is a classic story in aviation of a student who, after being fished out of the bay and brought ashore, marched up to the squadron commander and complained indignantly, "Sir, I had the stick all the way back, but the nose wouldn't come up." It was funny at the time. But it is ignorance of fundamental principles like this which causes accidental spins.

Even if a student does think of pushing the stick forward, he may be in so much of a hurry that he fails to recover complete control before he pulls it back again. In 1925 a student was up on his official stunt check. He had to perform certain stunts, of which he had finished all but the last, the falling leaf. Every time he tried this, he fell into a spin. In pulling out of these spins, he lost more altitude than he realized. Finally, getting into another spin, he discovered that he was rather low. As a matter of fact, some instructors watching him estimated his height at better than 1500 feet. But he evidently thought he was closer, for he tried to pull out in a hurry. He stopped the spin all right. But he failed to give the plane a chance to pick up flying speed before he pulled the yoke back in the effort to regain level flight. Naturally it fell off into another spin.

This spin he also stopped. He still had comfortable room to dive momentarily and gain speed. But again he was in too much of a hurry to get the nose up. He needed to pause hardly two seconds to recover full control. But the ground looked close. So he drew the yoke back and threw the plane into a third spin.

In this way he stopped three spins. But each time he let himself be fooled into pulling back too soon. Undoubtedly he would also have stopped the fourth spin had it not been stopped for him by a large and uncompromising roof. From this, he was presently able to climb down, though somewhat bruised and battered. But the plane came down in pieces.

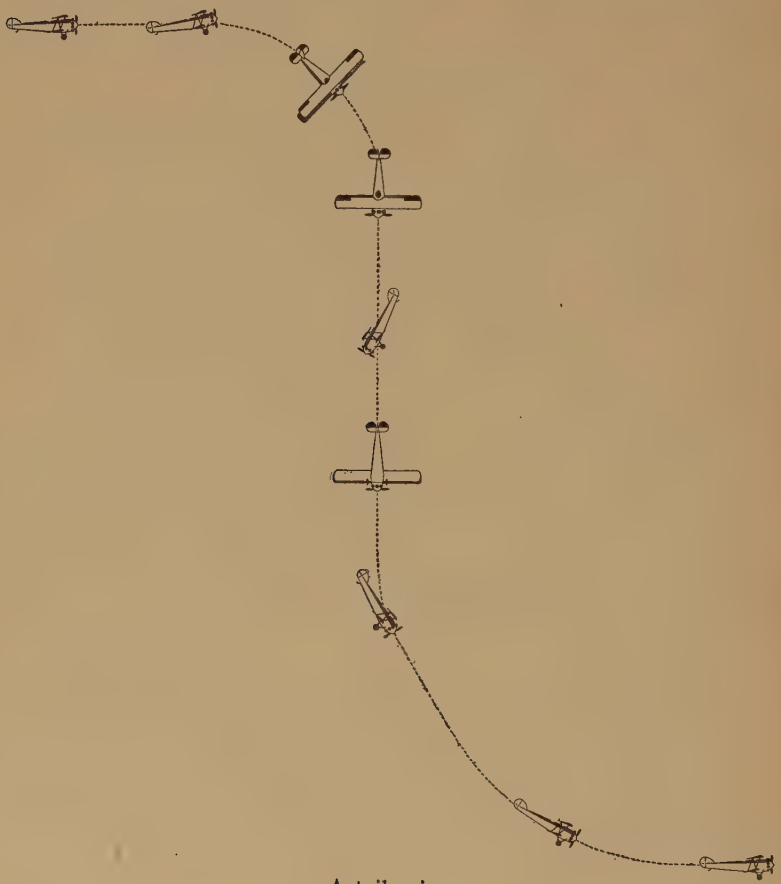
Contrast this with an incident which happened a few months later. An instructor was checking a student in a Jenny. The latter had been making good progress, and was considered capable. But on this check he got off to a poor start, making a number of mistakes. Finally, at about 500 feet altitude, the instructor closed the throttle for a spiral into the field. The student, apparently confused, let his nose come up too high and the speed dropped. A stall was imminent.

Now the instructor was fully aware of what was happening. He sat alert, hand poised just above the stick. But he did not touch it. The student was supposed to know enough to correct his own mistake. And he was entitled to a chance to do so. The fact that the ground was less than 500 feet below was no reason for getting excited.

However, for some reason or other, the student failed to catch the plane. It stalled and started to whip off into a spin. That was enough, so the instructor quietly took control. Without haste he eased the stick forward and put on opposite rudder. The spin was stopped after hardly half a turn. Nor did the coal pile immediately below hurry him. He paused just long enough to pick up safe speed, then pulled the stick smoothly back. When he leveled off he still had 300 feet of altitude left. Nor did he consider the episode an emergency. So far as he was concerned, it was all in the day's work.

This same instructor made some tests to determine how

long it takes to come out of a spin. With a stop watch he took the time from the instant he pushed the stick forward until the plane was in level flight. His average time was



A tail spin.

three and a half seconds. The altitude loss was too small to be read accurately from the altimeter, but could hardly have been much over 100 feet. Of course such quick re-

covery means that the plane is brought out with just a bare trace of flying speed, and must be kept out of another spin with the rudder. But, in a training plane, anybody ought to be able to come out in twice that time. No more than 200 feet altitude should ever be needed.

Ability to stop a spin in a hurry is sometimes essential. In 1926 an instructor had a student up on a crash check. The student had spun into the bay two days before and, according to established procedure, was required to pass two checks in order to continue soloing. He had already failed on the first check. This was his second. His work so far had been doubtful, neither definitely good nor bad. The instructor was anxious to get a clear-cut indication of what he could do. So he headed the plane inland over the beach and cut the gun. This required a half-spiral back to water.

The plane was just far enough inland so that it was doubtful whether it would reach the water without reopening the throttle, which the instructor was holding closed. It was up to the student to try it, but to keep flying speed at all costs. If he reached the water, well and good. If not, he must keep his speed and level off over the sand. It would then be up to the instructor to give her the gun. The student's sole responsibility was to spiral safely.

He entered the spiral and started around toward the water. But the spiral was flat. And he had on too much rudder, resulting in a moderate skid. The instructor sat alert, tensed for action. The speed did not quite reach the danger point, however. It was uncomfortably low. But there was still a slim margin left.

Thus they came around over half of the way. The plane hovered along on the verge of trouble, dropping lower all the time. The instructor estimated that it would just barely reach the water's edge at a safe speed. But the nose could

not be pulled an inch higher. The glide was as flat as it could possibly be.

Apparently, however, the student did not agree with him. At a height of fifty feet, he suddenly decided that he could spiral more sharply. This he proceeded to attempt. And his method of doing it was by pulling the yoke back and kicking the rudder.

Instantly the slim margin of speed was washed out. The plane gave the warning lurch that means a spin and started to fall off. The instructor, alert though he had been, was almost caught by the suddenness of the student's action. It gave him a bare split-second to act. But on the instant his hands had shot at the yoke. The beach was only fifty feet below. But there was not a trace of indecision in his action. It was forward that the yoke went. And at the same time he kicked hard opposite rudder.

To the student, the sand seemed fairly to jump up at him. He shut his eyes for the crash. But the instructor's movements were precise. A touch on the elevators checked the falling nose. Unhurried by the looming beach, he paused a fraction of a second to gain a trace of flying speed. Then a delicate up pressure lifted it gently. He had only a thread of speed. But his sensitive fingers utilized every ounce of control and brought the plane up, quivering but safe. It cleared the beach by ten feet as he opened the throttle once more.

Teaching a student to keep out of spins is one of the most important things in dual instruction. It cannot be neglected without seriously jeopardizing his safety. But it is a comparatively simple matter. After stalling the plane twenty or thirty times, he learns what stalls are like and how to avoid them. And if, by any chance, he should stall, he would never pull the stick back. Instead, he would rec-

ognize the situation, ease the stick forward and recover control. The records of actual training operations show that students who are thoroughly instructed seldom get into accidental spins.

When you go into a spin with the instructor, keep your eyes on the instrument board. If you try to look around, you will get dizzy. Look straight ahead.

When you want to come out, don't slam the stick forward with a bang. If you get it much forward of neutral, it will throw the plane into too steep a dive. Ease it quietly forward and neutralize the rudder. The plane can't go on spinning when you have the stick in neutral. If you want, use opposite rudder. This stops the spin a little more quickly.

Be sure you wait long enough to pick up your speed before you pull the stick back. It takes only a second or two. That means the difference between control and another spin.

Don't be afraid of spins. There is nothing mysterious about them. A spin can't hide behind a cloud and jump out on you as you go by. It is nothing that can clutch at you and drag you out of the air. It can happen only if you make a serious mistake.

The one thing you must do to avoid a spin is to keep flying speed. If you never climb steeply, glide flat or skid violently in a turn, you cannot lose control. These three things are easy to recognize. Look out for them and you will never get into an accidental spin.

CHAPTER XV

SOLO FLYING

PRESENTLY the day comes when the student finishes his ten hours of dual work. By this time his instructor has formed an opinion as to whether or not he can fly. This opinion must carry considerable weight. Unless a check flight is given, it should be decisive.

But if the school is a large one, there will be a check flight with the Chief Instructor. The latter rides with the student, directing him to execute various maneuvers. After watching his work in these, he decides whether the student is qualified for solo.

At Pensacola a checking system is in effect which requires two out of three votes on each student when he completes his ten hours. The instructor has the first vote. Then the student goes up for a check with the Chief Instructor, who has the second vote. Should they both agree that he is qualified for solo, he gets a plane at once. If they decide that he is not qualified, his flying is suspended. In case they disagree, a third check is given by another instructor, whose vote is decisive.

This is a tense time for students. The solo check, and all hope there will be only one, is looked forward to with anxiety. When the time comes to climb into the plane, the average student feels as if everybody on the station had stopped work to watch him. This is his chance to show that he has the makings of an aviator. He must do or die, and he taxies out all keyed up to do his best—which is the

chief reason why he seldom does it. Experienced instructors always expect their students to fall slightly below the standard of their previous work on account of this nervous tension.

But it is a good test of the student's steadiness. While his own instructor was in the forward cockpit, he knew that a single mistake would not count. But if he goes up solo, he will no longer have this assurance. There will then be nobody to help him out. Any tendency to be disconcerted by the absence of the instructor will show on the check, and can be taken into account in considering his fitness for solo. However, if the student has been doing reasonably well in his dual work, he has enough leeway to make a few mistakes and still qualify.

For nothing like perfection is ever expected—or found—on solo checks. The Chief Instructor has one primary question in mind, "Is he safe?" To determine this, his work is considered very carefully. The minor errors always found are not considered important. Moderate slips and skids, inaccuracies in leveling off, sloppy spirals and poor approaches are taken as a matter of course. But if a man skids badly, even though he does not actually stall at that particular moment, there is no assurance that he might not skid a little worse on a solo flight and go into a spin. Or if his landings are uncertain, could he get the plane down right side up? His work need not be smooth. But before he soloes, he must demonstrate, not only that he can fly without loss of control, but that there is no apparent danger of his even approaching loss of it.

There are, of course, some doubtful cases. Flying ability cannot be measured with mathematical precision. Judging it is a matter of opinion. But the opinion of an experienced instructor is surprisingly accurate. So the number of bor-

derline cases is not great. And, if a few mistakes are made, they are far more than offset by the averting of many potential crashes.

At Pensacola, about 75 per cent of students qualify for solo after ten hours. The remainder appear before an Advisory Board. Any who seem to be almost ready to solo are allowed three hours' extra instruction. Some of these later qualify. Those students who fail to qualify are dropped from training.

To a student who does not pass, his failure is of course a disappointment. But he must realize that his inability to fly reflects no discredit on him whatever. It simply means that he is not cut out for aviation. A little reflection will show him how much better it is for him to stop now than to solo and run the risk of an accident, either during the course or later on. The instructor who recommends that he be dropped may be saving his life.

The student in a civilian school is certainly equally interested in his own safety. The best way for him to insure it is to take a check with an experienced instructor, to get the latter's opinion as well as that of his own instructor, and then to abide by their decision.

Solo with less than ten hours of dual instruction is not advisable. Of course, many men have in the past done this. And frequently, after perhaps seven hours of dual work, a student seems to be ready to go up alone. But there is no assurance that he has yet developed the necessary steadiness. Seven hours is rather short for this. And if he were to solo, the nervous tension involved might easily affect his work.

In the days when solo with seven hours was permitted at Pensacola, a student was recommended by his instructor at the end of that time. He went up with the Chief Instruc-

tor and passed a good check. Then he went out alone. When he came in to land, the emptiness of the forward cockpit was decidedly on his mind. He was on his own. No mistakes could be made now. There was nobody to keep him out of the bay. This must be a good landing. He gathered himself for the effort. As a result, it was a very bad landing. He made eight long graceful bounds through the air before he finally managed to get the plane to stick to the water.

Even when a student is able to handle the plane well after seven hours, the other three hours are necessary. They give him the experience he needs to develop steadiness and confidence in himself. Then when he soloes, he is not likely to be over anxious on account of the instructor's absence. A full ten hours is now required at Pensacola regardless of apparent ability.

Let us assume that you have passed your check and are ready for your first solo. You are assigned a plane at once, and out to it you go. As you walk along the line, you feel the elation of your successful check. You were sure you could make it. But it was good to hear the Chief Instructor say so. And it was a pretty fair check. Some slips and skids, of course, and you leveled off too high once and dropped her on a little hard. You could have done better. But it wasn't bad, and he said you were getting along all right.

Just then you reach your ship. And it will be an excellent idea to stop thinking about the check and think about what is ahead. You've learned a lot. But now you've got to remember it. Nobody is along to remind you of anything. Is the plane ready? Plenty of gas and oil? Controls all right? Landing gear in good shape? Better look

her over carefully. You're the pilot now, and if anything goes wrong it's up to you.

If there is a cushion in the forward cockpit, take it out. And buckle the safety belt. There mustn't be anything there which might foul the controls. Are there blocks under

U. S. Navy photo.

A Fighting Plane.
Boeing single-seater fighter with 425 H.P. Wasp engine.

the wheels? Is the windshield clean? And have you enough cushions for yourself?

Then you climb in and start the engine. Don't be in a hurry to taxi out, however. Remember, that engine is the one which is going to take you up alone. You know how to make a forced landing. But your first solo is not a very good time to exhibit your ability in that line. Better to

make sure the engine is running right so you won't have to. Look at all the gauge readings carefully. Get her well warmed up. And see that she turns up plenty when you open her up.

Now you are ready. At your signal the mech pulls the blocks. You open the throttle cautiously and the ship begins to move. Take it slowly now, and keep her under good control as you taxi out. Which way is the wind? You looked at the sock when you climbed in, but check up on it again. And remember the field rules. Don't get into anybody's way.

At the leeward end of the field you swing around, get the plane headed straight into the wind and stop. Now look all around very carefully. You don't want to have anybody near enough to bother you on this take-off. If you think anybody is going to get uncomfortably close, wait. And while you are stopped, make one final check-up. See that your engine gauge readings are all right. Be sure the engine sounds right. Wipe any specks off your goggles. And feel your safety belt to see that it is tight.

Now all you have to do is to drop your hand to the throttle. Perhaps, for a moment, your heart beats a trifle faster. And your breath comes a bit quick. A first solo happens only once in your life. But you have ten hours in the air back of you. You know how to handle a plane. And, after all, this is only a few minutes' flight around the field. You drop your hand and push the throttle open. The engine answers with a rush of noise, the propeller blast whips past, and the field starts to slide under you. Then the jarring of the wheels ceases. You are in the air.

For a moment you are aware of a certain surprise. Flying alone seems quite natural. The plane acts just as it

always did. And you find yourself doing things in a perfectly matter-of-fact way. You move the stick and rudder bar instinctively, keeping the plane level. You raise the nose to the climbing angle you want. It is no effort whatever to hold the ship on a straight course. You glance casually over the side, and the field below looks just as it always has. The engine is turning up 1700 revs, and all the gauges are reading right. You go ahead and fly just as you have been doing. And you almost forget you are alone.

It is a good idea to climb 500 feet or so before you start a turn, just to be sure you have plenty of room. Then take it easy and make a comfortable turn. But don't be afraid to bank and try to skid around. Handle the plane just as you have been doing. As long as you do, it can't act any differently.

You may, however, be surprised when you look at the altimeter. Without the weight of the instructor, the plane climbs faster. So you are likely to find yourself higher than you expect. However, since you have been up for stalls and spins, you are familiar with altitude. And if you throttle down and keep the nose on the horizon, you won't get any higher than you want.

Two or three circuits of the field will be enough. Then come in for a landing just as you have been doing with your instructor. But if you think the approach is not just right, don't hesitate to use the gun. If you seem to be undershooting, give her a few shots and pull her along. Don't run any chances of clipping the edge of the field too close. If you are overshooting, give her the gun and go around again. You have plenty of time, and can go on making passes at the field until you make one that just suits you. Then feel out your landing normally, using the stick freely and easily. Finally, as the plane stalls, pull the stick fully

back and there you are. Perhaps you hit a little harder than usual. But that is nothing. The main thing is that you are down right side up. At last, you can call yourself an aviator.

But if one solo flight makes a man an aviator, it does not make him a competent one. It merely begins the next step in training. He has learned the fundamentals of practical flying. But he lacks the experience to apply them under operating conditions. And he has not yet acquired the advanced knowledge needed to meet situations which may arise. He must now go on with his work to get the necessary experience and training. To this end he soloes daily, weather permitting. One hour is the best time, though flights may be a little longer or a little shorter.

The student should plan his flights carefully in order to get the maximum value from them. To do this, he follows out the same procedure as during dual instruction. In a landplane, he makes continuous circuits of the field, landing once on each circuit. Each time he reopens the throttle and goes on without stopping. In a seaplane, he goes to the leeward end of the bay and starts a succession of landings into the wind. On reaching the opposite shore, he turns and flies back to the leeward side to start another run. Always it is landings which determine the plan of the flight. Since they are the most difficult thing for him, he must get the maximum number of them into each hour. He can get enough practice in turns during the intervals between them. But whatever he does, he must always be doing something. Mere aimless flying around the sky is profitless. Every minute should be spent in practicing elementary maneuvers.

However, about every twenty minutes he should let the

plane come to a stop after a landing. Then he should relax for a minute's rest. He will do better work if he breaks up his flights like this.

After each five hours solo, there is a check flight with the instructor. These are very important, and should under no

U. S. Navy Photo.

SINGLE-ENGINED BOMBING PLANES.
Martin T-4-M torpedo and bombing planes with 525 H.P. Hornet engines.

circumstances be omitted. Satisfactory progress depends on them to a considerable extent. For, as we have seen, the student's work when he soloed was far from perfect. It was safe. But it showed definite errors. He may, for instance, have been skidding his turns to some extent. He may have

been leveling off a little too high and dropping on too hard. Or, in some cases, there may be a relapse after soloing into serious faults previously eliminated, such as gliding too flat. It is essential that the instructor check up on him and see what he is doing. Unless he is steadily cutting down his mistakes, he is not making the most of his time in the air.

At Pensacola, checking continues at regular intervals throughout the course. There is first a flight with a check instructor, who reports what errors he found in the student's work. This is followed by a flight with the student's own instructor, who spends as much time as necessary to correct the more serious mistakes. In case a check is reported as unsatisfactory, a second is given, and if necessary a third. A student who fails on two out of three checks appears before the Advisory Board. The standards required rise steadily as the course goes on. A certain number of students, failing to meet them, are dropped. But the majority show satisfactory progress.

As soon as he is sure that he can make good landings consistently, the student should commence the development of precision. On every approach he picks a spot at which to aim. Then he tries to land as close to it as possible. At first, of course, he is not particularly accurate. And the attempt to be accurate must never be permitted to distract his attention from making a safe landing. But as he goes on, he will gradually increase is ability to land with precision.

No flights should be made beyond the immediate vicinity of the field. The student is not ready for cross-country work yet. That will come later. For the present, he needs to be within easy reach of the field in case of engine trouble or any other difficulty. In a seaplane, never get beyond

gliding distance from water. A forced landing on land would wreck the plane.

All flying must be done in compliance with the Air Traffic Rules. The student must know instantly what is required of him in any situation. Other pilots expect him to do the right thing. Hence study of the rules is imperative.

No passengers are ever to be carried during elementary training. It is inexcusable for a student to take any one up. Even though there is no legal objection, he has not the moral right to do so. The other man knows nothing about flying and might think it was all right. It is up to the student to show his sense of responsibility by refusing to carry any one until he is fully competent to do so.

Some suggestions about solo flying. Keep right after your work. A few days without a flight will retard your progress distinctly. You are still in a preparatory stage, and cannot stop without slipping backward. Keep at it until you qualify as a pilot.

However, if you do not feel well, don't try to fly. You will simply waste your time. If for any reason you should be unable to fly for a week, go up for a check with your instructor before you solo again. This is a safety precaution, in case you should misjudge your first landing badly.

Keep busy all the time in the air. You are up there to learn to fly. And the only way to learn is to do things. Keep taking off, turning, spiraling and landing. You must get practice in these things. Joy-riding teaches you nothing. That will come later on.

One young student at Pensacola was so thrilled at passing his solo check that he spent most of his time soaring around the sky. He used to tell his friends of the pleasure of cruising high above the station. But unfortunately, on his ten-

hour check, his landings were not so good. He did no more sky riding. And shortly thereafter he departed from the station for more prosaic duties elsewhere.

Keep awake. Your instructor is not with you now. You must see things for yourself. Watch your instruments. Be sure you spot every plane that comes near you. Look at the wind-sock every time you come around. Never let anything happen that you don't know about.

You should be able to maintain a good climbing angle now even when the horizon is obscured by haze. If your feel of the air is adequately developed, you can judge it by your speed and the feeling of the elevators. Whenever this condition occurs, practice climbing at a moderate angle.

Don't fly in rain or fog. If the weather starts to get bad, come in and land. Should you run into a shower, don't be alarmed, however. The rain will not bother you any. Only don't try to wipe your goggles. You will simply smear them so that they blind you. If you let them alone, you can see well enough in spite of the drops on them.

In case there appears to be anything wrong with the engine, come in at once. If the oil pressure drops or the temperature goes up, or if it starts to miss, don't take any chances. Bring the plane in before you have a forced landing.

Keep out of slip-streams. A slip-stream is the wash from the propeller of another plane. It can be felt for ten or fifteen seconds after the latter has passed. If you were to get close behind the other plane, it might blow you into a spin. In case you get into a slip-stream accidentally, nose over and drop out of it.

Never try anything you have not yet been taught. In turns, bank enough, but no more steeply than during dual work. Don't try any flipper turns. Your instructor will

check you on spins when he goes up with you. But don't try any yourself yet. Don't even stall the plane intentionally. Fly carefully until you are sure of yourself.

Don't try to show how good a pilot you are. Even if you think you know quite a bit about flying, keep it to yourself. A student was once watching instructors landing into an offshore wind. They would come spiraling in, headed straight toward the beach, and land close to it. Then, when the plane lost its speed and settled into the water, they would have only a few hundred feet to taxi. The student admired their precision greatly. So when he went up for a solo flight, he undertook to try it himself. But, as he came gliding in, the hangars loomed closer and closer. He began to wonder if he could be too far in. Just to be on the safe side, as he thought, he eased the stick forward and tried to put the plane down. But, unfortunately, it still had plenty of speed. Instead of landing, it hit and shot twenty feet back into the air.

The astounded student hastily gave her the gun. The plane picked up just enough speed to stagger over the top of a low storehouse. The float cleared it by inches. But it did clear. And all would have been well with him but for a church across the road. Its steeple, sticking upward like a warning finger, nipped his left wing and deposited him, much embarrassed, in the churchyard.

Always be ready for engine failure. It is not likely to happen to you. But if it should happen, you cannot afford to be caught napping. Every time you take off, think what you would do if the engine quit cold. While you are circling the field, have your mind made up every instant which way you would turn. A forced landing is easy when you are ready for it. And if you are ready, you need not worry about it.

Always fly the plane. Never let it fly you. If you want to turn, bank it over and turn. Never hesitate, wondering whether you can do something. If you have learned how to do it, go ahead and do it. Don't let the plane ride you around. You are the pilot. And, within its capacity, the plane will do whatever you want it to.

CHAPTER XVI

STUNTS

After he has completed fifteen hours solo, the student is ready to learn something new. The first thing he is taught is how to make reverse control or "flipper" turns. These are not, strictly speaking, classed as stunts. They are simply turns in which the plane is steeply banked, at an angle of more than 45 degrees. But they involve a new use of the controls, for the functions of the elevators and rudder are interchanged. The elevators are more nearly vertical than horizontal, and hence their chief function is now to keep the plane turning. The rudder, on the other hand, is more nearly horizontal than vertical, and serves principally to keep the nose level. Hence the name, reverse control turn.

Such a turn is entered in the same way as an ordinary turn. Until the wings pass a 45-degree angle, the controls are handled similarly. But as this point is passed, the stick must be pulled gradually back. This raises the elevators, and the pressure on them keeps the plane turning just as the rudder does in a normal turn. At the same time the rudder is eased off, as its pressure would tend to depress the nose. It is now used to keep the latter on the horizon.

A bank of about 60 degrees is sufficient for the student. At this angle, of course, the controls are not completely reversed, and elevators and rudders must be used together both to keep the plane turning and to keep the nose level. But the stick must be held appreciably back of neutral. It

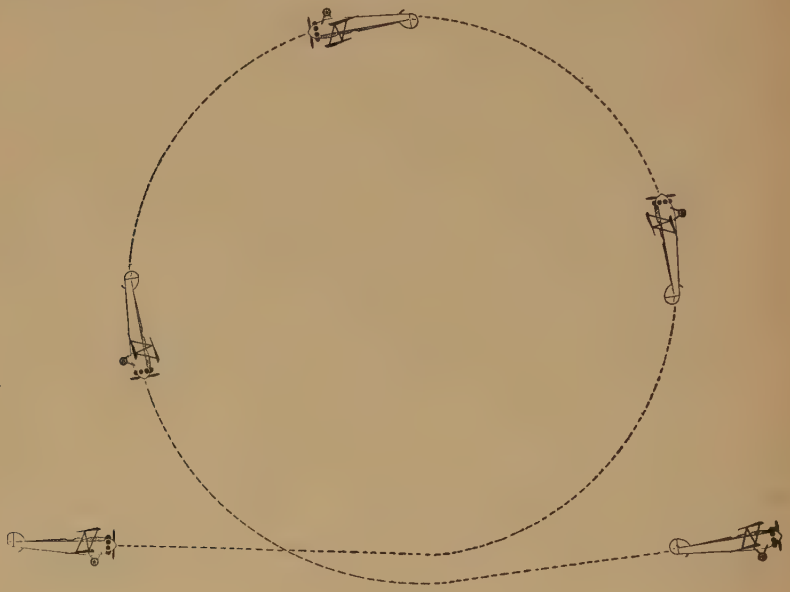
is also necessary to keep a slight pressure on the ailerons, in order to prevent an increase in the bank. In this position the nose swings rapidly around the horizon, and the plane turns with a small radius. The instructor may bank as much as 75 degrees, but beyond this point the average plane cannot be satisfactorily controlled. To come out, opposite aileron and opposite rudder are applied just as in a normal turn.

Slips and skids occur in flipper turns just as in normal turns. If the stick is not held back far enough, the plane will not turn fast enough and will consequently slip. If it is held too far back, the plane will skid. Any marked skid will result in an abrupt power spin. Practice in recovering from such spins is essential. Usually the student will fall into several accidentally. But if he should not, the instructor will throw him into several. The important thing is to close the throttle. As soon as the engine is throttled down, the spin becomes a normal one. The plane will then come out with the controls neutralized.

Reverse control spirals are also practiced, spirals in which the plane is banked more than 45 degrees. The stick and rudder bar are handled as in a reverse control turn, except that down rudder must be used occasionally to keep the nose down and retain speed. Two complete 360-degree spirals ought to be made with an altitude loss of not over 1000 feet.

Some instruction in side-slips is also needed here. If the plane gets to slipping violently sidewise, hard down rudder must be used to recover. This swings the nose down, turning it in the direction which the plane is actually going. At the same time the engine is throttled down and the wing brought up with the ailerons. This throws the plane into a normal glide.

During the period from fifteen to twenty hours solo, the student spends about one-third of his time on reverse control flying. The remainder should still be devoted to elementary work. Later on, after he can make good turns, he tries figure eights. These are a series of reverse control turns in which the plane describes a figure eight above two



A loop.

points on the ground, each of which is made the center of one loop of the eight.

After twenty hours solo, the student is ready for instruction in stunts. These are not an essential part of the course. A man can fly safely without them. But they have a good deal of training value. Hitherto much emphasis has been placed on retaining control. The student has been required to fly carefully, making every effort to prevent a stall.

Hence he may still think of loss of control as something which might involve danger if allowed to occur. But now he is taught deliberately to throw the plane out of control and then to recover headed in a different direction. He learns that, at a safe altitude, a stall is a simple routine maneuver. He goes through it as a matter of course. Recovering from it is easier than making a landing. He becomes familiar with other unusual positions of the plane and learns that, no matter in what attitude he finds himself, he has only to neutralize the controls in order to come out in a normal dive. So he gets over any possible uneasiness he may have had on the score of loss of control; and this, in its turn, results in a substantial increase in his self-confidence.

The stunts usually taught are the loop, split-S turn, falling leaf and precision spin. A loop is executed by pulling the stick gradually back, bringing the plane up and over. Excess speed must first be gained by nosing down about ten degrees with the throttle wide open. Then the backward movement of the stick is started. The nose begins to rise, and goes steadily up. In a moment it is pointing straight up. Another couple of seconds and the plane is on its back. Here the stick is pulled fully back and it drops into a normal dive. The elevators must be eased for a moment to pick up speed. But then the nose can be brought up to level flight again, completing the loop.

A loop is not particularly difficult. The main thing is to pull the stick back at the proper rate. If it is pulled back too fast, the plane will squash through the air and slow down. If it is pulled back too slowly, speed will be lost while the plane is headed upward. The student must learn just how fast to raise the elevators so that momentum will not be lost.

If a mistake is made and speed is lost on the way up, hard rudder must be applied. This throws the plane off into a side-slip, from which it can be pulled out without difficulty. It is very important that the rudder be applied in time, as otherwise a snap-stall might occur. This is a stall in which the plane loses speed while headed vertically

Courtesy of Waco Aircraft Co.

Upside down in a loop

upward. It will then drop abruptly to a position headed vertically downward. This results in considerable shock.

In 1919 a pilot was looping in an old N9 seaplane at 5000 feet altitude. The 100 H.P. engine then installed in that type was barely powerful enough to pull the plane around in a loop even when running its best. Perhaps the motor in this particular plane was not turning up enough, for some instructors watching it from the beach saw the pilot snap-stall twice.

"He'd better not try that again," somebody remarked, "or he'll be throwing the engine out of that crate."

It was only an idle remark. But just then the pilot, attempting to loop a third time, snap-stalled once more. As he did so, something small and dark left the plane. Instantly everybody's eyes were riveted on it. It could be only one of two things—the engine or the pilot. (And there were no parachutes in those days.) But at that altitude it was impossible to tell which it was.

The thing dropped like a rock. Every eye followed it down. As it neared the bay, it was streaking through the air with meteoric velocity, emitting a loud whining drone. It was going too fast to be clearly visible. But nothing that looked like arms or legs could be distinguished. Everybody drew a breath of relief. It must be the engine.

It hit with a reverberating thud just offshore, sending a geyser of water a hundred feet in the air. Then everybody's eyes turned toward the plane. The loss of the motor had thrown it so badly out of balance that it was hopelessly out of control. But it was now so light, without the weight of the engine, that it was falling quite slowly. In fact, it was not even nosed down. Instead it was fluttering down practically level, but spinning slowly around like a big lazy top. It followed the exact path of the engine—a vertical drop. But it took fully five minutes to reach the bay. When it finally got down, it flopped heavily into the water like a box kite, but still perfectly level and sitting erect on its float. The wrecking barge, already on its way out, was sent back. A motor launch ran a line to the float, took the plane in tow and hauled it back practically undamaged. The pilot was likewise unscratched. But he was so dizzy from the long whirl that it was ten minutes before he could stand up straight.

In a split-S turn, the plane is stalled and allowed to fall off. The stick is pulled quickly back, raising the nose, while at the same time hard rudder is applied. As the plane stalls, the rudder causes it to fall off toward that side. The wing goes down until it is pointing vertically toward the ground. The nose swings toward the same side and then keeps on going down until the plane is diving. When it is pulled out of the dive, it is headed in the opposite direction. A split-S is the quickest way to turn a plane, though some altitude is lost doing it.

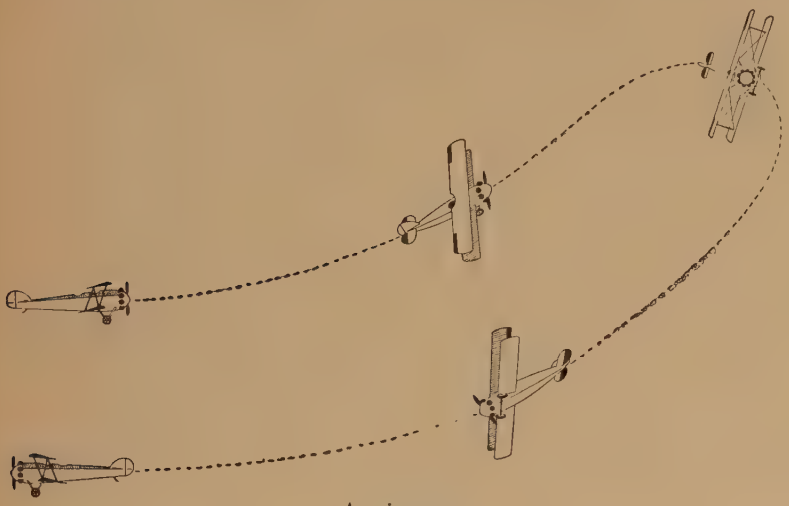
In a precision spin, the student brings the plane out headed in a particular direction. Hitherto, with the controls simply neutralized, its rotation has been slowed down more gradually. It would make perhaps half a turn before it stopped spinning. Now the student learns to stop the spin sharply by using hard opposite rudder. As the plane reaches the heading he has picked out, he neutralizes the stick and steps on the rudder. The pressure of the latter stops the rotation almost instantly. After a little practice, he finds that he can bring the plane out headed in any direction he wants.

A falling leaf may be taught, though it is of less importance. In it, the plane is allowed to fall off successively right and left, thus descending in a series of swoops like a falling leaf.

Some other stunts may be mentioned here, though the student is not yet ready for them. A wingover is a climbing turn followed by a diving turn. Entering it, the plane is banked over as if for a flipper turn, but at the same time the nose is pulled steadily up. This produces a zooming turn steepening rapidly in bank. When the plane is at right angles to its original course, banked 60 to 70 degrees, sharp down rudder is applied. This drops the nose into the posi-

tion of a flipper spiral, except that the engine is running. From this it is pulled out headed in the direction opposite to its original course. Wingovers are usually done in series, consecutively right and left.

A properly executed series of wingovers is one of the most graceful maneuvers of flying. It is also one of the most difficult to do well. There should be no abrupt movements of the controls. The plane rises and banks at a steadily in-



A wingover.

creasing rate to a maximum, then the nose turns downward and the dive and bank decrease gradually to straight and level flight. Everything is done smoothly and evenly. Flying speed is retained throughout, and the plane is at all times under complete control.

The student should try wingovers after about thirty hours solo. They are the best test of a man's air work, for a high degree of coördination of the controls is required to avoid slipping, skidding or stalling. An experienced instruc-

tor, watching them from the forward cockpit, can estimate accurately a student's feel of the air.

In a barrel roll the plane rotates around the fuselage. This is accomplished by applying all controls fully and

Courtesy of Waco Aircraft Co.

A barrel roll.

simultaneously. Full up elevator, right aileron and right rudder will make the plane roll over sidewise to the right like a barrel. When it has completed its rotation, opposite aileron and rudder will stop it in straight and level flight again. This maneuver is, however, too much of a trick for

the beginner. It should not be tried until after fifty hours solo.

An Immelmann turn is a half-loop and a half-roll. The plane is started through a loop. But when halfway through it, upside down, full elevator, aileron and rudder are applied. This rolls the plane over sidewise and it emerges right side up in level flight, higher than before and headed in the opposite direction. The name is taken from the famous German ace, Immelmann, who is credited with originating the maneuver. A comparatively high-powered plane is required in order to execute a good Immelmann turn.

The regulations of the Department of Commerce require that all stunts be completed above 1500 feet altitude. And over certain specified areas stunting is prohibited at any altitude. It is imperative that these regulations be obeyed. They are intended, not only for the protection of the pilot, but for that of other planes and of people on the ground. Nothing is considered by experienced aviators as being dizzier than low stunting. It is the ultimate in foolhardiness. And more than one pilot who thought he was good enough to get away with it has paid the penalty of his rashness.

But at reasonable altitudes stunting is perfectly safe. The plane cannot get into any position from which it will not emerge in a normal dive. The controls need only be put in neutral. So long as the plane is high enough, it will straighten out promptly. Easing the stick back will then bring it up into level flight once more.

Stunts may be a little disconcerting at first. You may find yourself unconsciously clenching your teeth as you start into a loop. But you will quickly learn that in reality they

are quite simple. Even if you make a mistake, there is nothing to worry about. You will undoubtedly spin out of some of your first loops and split-S turns, due to pulling the stick back too fast. But by now you are so familiar with spins that you recover without the slightest hesitation.

In flipper turns, you will be due for a slight start soon after you commence them. A steeply banked plane hits its own slip-stream every little while. It is shaken sharply, and feels as if it were going out of control. But nothing need be done. It will pass through the stream in a moment and get back into smooth air.

Don't forget to look at the altimeter. A seaplane student was once having a great deal of difficulty with the falling leaf. Every time he tried it he went into a spin. He was much discouraged. But, after a couple of days, he got a plane which was supposed to do it particularly well. He spun several times and lost altitude. But finally he got going just right. The plane fell first right, then left, in long, easy swoops. He was delighted. In fact, he was so delighted that he forgot to watch the altimeter. The first thing he knew there was a crash and a splash. Then he found himself sitting in the bay, looking at an altimeter needle which registered zero.

Don't spend all of your time stunting. It is more fun than circling the field in a monotonous succession of landings. But you aren't a finished pilot quite yet. You still need some elementary practice. Spend at least a third of your time going through the old routine.

CHAPTER XVII

PRECISION LANDINGS

Ability to land a plane where he wants it is the mark of a capable pilot. It is not enough merely to land somewhere in a large field. A man must be able to put his plane down with precision at any designated spot, either with or without the engine. Development of this ability is the most important part of advanced training.

For the last ten or fifteen hours the student has been trying to attain some degree of precision in his landings. Consequently he already has an idea of how to handle the plane. But now he concentrates on precision. With his instructor, he goes to some smaller field in the vicinity, where accuracy is needed to land at all. The instructor will select a field where there are no large obstacles to interfere with an approach, and will make two or three landings himself. Then the student tries it.

The objective is to clear the last obstacle, a fence, road or whatever it may be, by a small but safe margin and with only speed enough to give good control. To accomplish this, the student first drops down fairly low while still some distance away from the field. At the same time he brings the plane directly into line with the path across it over which he wants to roll. This is done to avoid any necessity for a low turn, as banking would interfere with precision. From a height of some thirty feet, while still five or six hundred feet away, the plane is allowed to drop gradually.

Accuracy now depends on sensitive use of the throttle and elevators. The nose is dropped only slightly, so that altitude is lost slowly, and the engine is kept running just fast enough to maintain sufficient speed for good control. Thus the plane is brought down until it reaches the edge of the field with its wheels from five to ten feet above the last obstacle. Here the throttle is fully closed and it is dropped to the ground and leveled off for a landing.

Accurate use of the throttle is very important. If the engine is running too fast, the speed will be too high and the plane will glide too far into the field. On the other hand, if it is throttled down too much there is danger of a stall. This, of course, must be especially guarded against, as losing speed too soon might let the plane hit something before reaching the field.

The instructor may take the plane into several new fields if there are any other convenient ones. In case the approach at any of these must be made over higher obstacles, he will very likely make a side-slip landing. This is a useful maneuver for getting into a small field. As the plane clears the last obstacle, the pilot banks sharply and at the same time applies hard opposite rudder. This, of course, throws the plane into a slip, and it drops quickly to the ground. But, instead of picking up excessive speed, as it would if merely nosed down steeply in a straight glide, it gains little or no excess speed on account of its sidewise motion through the air. Thus it can be landed in a much shorter distance from the edge of the field. Ability to side-slip to a landing is essential in getting a plane into a restricted space over trees, wires or other higher obstacles.

Another way of reducing the space needed for a landing is by fishtailing. The rudder bar is kicked alternately right and left with slow, heavy movements. The resultant swerv-

ing of the nose from side to side increases the air resistance and slows the plane down more quickly.

The next lesson is in landing accurately without using the engine. A mark is placed in the training field or, if flying a seaplane, a boat or buoy is anchored out. The instructor climbs up to two or three thousand feet, closes the throttle and spirals down. The objective is to land within 200 feet of the mark without opening the throttle again. The instructor will be able to land closer than this. But 200 feet is considered a fair requirement for students.

For the student, the first thing is to practice shooting the mark from a lower altitude. The best approach can be made from a position headed straight downwind at a height of 800 to 1000 feet with the mark directly to the side and not too close. From this point a spiral around to leeward is entered. The plane is banked just enough so that it describes approximately the arc of a circle with the mark as a center. Thus it remains at a constant distance while its altitude decreases steadily. The advantage of this is that it is possible to cut in anywhere. If the plane was low at the start of the spiral, it is swung in quickly. If its height was about right, it can be swung in when directly downwind from the mark. While if it was high, the spiral is carried past the downwind heading as far as necessary before cutting in. Thus provision is automatically made for a wide variation in altitude at the beginning of the half-spiral. If the plane was anywhere between 600 and 1200 feet up, it can be kept close enough to the mark for an accurate approach and can then be turned in at the right time.

When the student estimates that a straight glide will bring him to the ground at the required spot, he banks sharply and heads straight for it. The greatest accuracy is attained

by cutting in a little high, that is, so that in a normal glide the plane would land two or three hundred feet beyond the mark. If the distance was correctly judged, a moderate slip will eliminate the excess altitude and bring it down at the right place. If the distance was underestimated, a normal glide without slipping will still reach the point. While if it was overestimated, a steep slip will be required. This use of the side-slip is a vital part of precision landings.

After some practice in making the half-spiral from 1000 feet, the student will be able to land with fair accuracy. He then tries it from a higher altitude, two or three thousand feet. The objective now is to spiral down over the mark in such a way as to bring the plane into the same position, headed downwind at 800 to 1000 feet with the mark off to one side. If he can do this he can usually make an accurate landing. After a few tries, he learns to increase or decrease the bank in his spirals as necessary in order to bring the plane out into this position.

In all of these landings the requirement of flying speed must again be emphasized. The nose must be kept down. The glide must be safe. Any flattening of it whatever means the danger of a spin. Particularly in spirals is this important. The stalling point when steeply banked is considerably higher. Hence a sharp turn is safe only at high speeds. Nothing whatever must tempt the student into letting the nose come up. And he must avoid any tendency to skid, an error he is likely to make unless he watches for it. If he sees he is going to miss the mark, he must reopen the throttle and go on.

In all adequate courses, students are required to pass a precision landing test. The test in the elementary seaplane course at Pensacola is typical. A small boat is anchored out in front of the station. At an altitude of 3000 feet, the

student is required to cut his ignition switch and kill his engine. He must then glide down, making not less than two complete spirals, and must make a good landing headed upwind within 200 feet of the boat.

After the necessary instruction and solo practice, students are allowed three attempts at the boat shot. Most of them

Courtesy of Keystone Aircraft Corp.

A Twin-engined Bombing Plane.
Keystone Panther bomber, with two 525 H.P. Hornet engines, built for U. S. Army

make it on the first or second try. But some miss both of these. Then they have one more chance. Third shots are watched with interest, for students are likely to be in the mood to try to make it at any cost. Their vicissitudes are many and varied.

A student was one day coming down for his third boat shot. On his two previous tries he had overshot badly, glid-

ing over the boat and landing a quarter of a mile beyond it. And as he passed the boat this time headed downwind, his instructor, standing on the beach, saw that once more he was much too high. He circled around to leeward in a left spiral and got headed nearly upwind at least three hundred feet higher than he should have been. The instructor started to walk off in disgust. Then he stopped and stared. The student had suddenly thrown the plane over into a very steep spiral to the right, the opposite way. He was turning away from the boat, trying to make three-quarters of a spiral and get back to it. It was a long chance. And the instructor frankly did not believe he could make it. In fact, he half expected to see him lose his speed and spin in.

The student must have banked the plane over at least 75 degrees. Nothing less would have made it. The instructor held his breath, wondering if he had speed enough to keep control. Evidently he had, for he came all the way around with the plane cocked up like that. When he finally straightened out about fifty feet from the water, the boat was right square in front of him. Before the instructor had recovered from his astonishment, he had made a good landing alongside it.

Another student got himself right over the boat at a low altitude, the worst position possible. He should have given up the shot, straightened out and made a safe landing. Instead he tried to turn downwind. He banked her far over in a tight spiral and promptly lost his flying speed. The plane, of course, flipped into a spin. He was too low to pull out of it and went in the bay. His precision, however, was excellent. When he fell, he hit squarely on the boat and sank it. However, as this could hardly be interpreted as a good landing, his accurate aim was wasted.

It is very important, with the engine dead, to make a good

landing. For, if the landing should not be good, there would be no chance to recover with the throttle. And in case the plane should stall at any height, it would probably be damaged when it dropped. One student had a sad experience through failure to make a good landing. It was his third shot, and as he came spiraling down, he was tensed to do his utmost. But he was too far away. However, he swung in toward the boat and, trying to make it, held his nose unduly high. It was not high enough to cause a spin. But the plane lost flying speed and got to squashing badly. He might have gotten away with it even then if he had pulled the yoke back hard just as he reached the water. But he failed to do so, and hit flat and squashing. The plane rebounded and soared through the air in a long leap. Then it dropped from a height of about ten feet.

However, when it came to rest, nothing seemed to have happened to it. It was floating normally. And it appeared to be just close enough to the boat. The student, with a breath of relief, climbed out of the cockpit. It looked as if he had made it.

He got out the crank and started up the engine. Then he climbed back into his seat. But as he did so, a peculiar splashing noise reached his ears. It sounded like something slapping the water with rapid beats. And, when he looked at it, the nose seemed to be lower than it should be. Startled, he began to climb out once more to investigate. But before he could do so, the plane rolled gently over on its nose, burying its engine in the bay and sticking its tail up to the sky.

When he hit, he had knocked a hole in the bottom of the float. Water had commenced coming into the forward compartments. It had been mounting while he was starting the engine, and as the bow of the float sank, the propeller

blades, dipping into the waves, had made the peculiar noise he had heard. Then, before he could get out, the bow compartments had finally flooded and the plane had tipped over on its nose.

The accuracy of a boat shot is observed from the lookout tower by means of ring sights. In 1918, however, an officer was stationed in the boat as observer. He estimated the distance of the landing and decided whether or not the shot was satisfactory. Of course, the closer to the boat, the better the shot. At least, this was the rule until one student demonstrated that accuracy can be carried too far.

On this particular day, the observing instructor had been having a dull time. Only two students were scheduled to shoot the boat, and one of them had already missed it by half a mile. The midsummer sun was beating down vertically, undimmed by the smallest cloud. The scrap of awning in the boat was a feeble protection against its rays. The magazine which the instructor had brought proved tiresome, and he lay at full length on the cushions, yawning and wondering if he could keep awake till the other student got down.

Presently he saw the plane coming. Without getting up, he watched it idly. The man would probably miss the boat by a mile anyway and his morning would be wasted. Why get up and perspire about it?

However, the student seemed to be making a fairly good shot. As he spiraled around the boat, he looked to be about the right height. And just about far enough away. He had a chance to make a good shot out of it, the instructor decided. If he didn't boot it away by turning in too soon—or else too late. Most of them were doing one or the other. He hadn't seen a really accurate boat shot for a week.

But no, this man was turning in just about right—banking her well over and cutting in sharp. Now he was straightening out, headed right for the boat. Looked as if it was going to be a pretty fair shot after all. Might even be worth getting up for. The instructor climbed leisurely to his feet.

U. S. Navy Photo.

A Twin-engined Amphibian Cabin Plane.
Sikorsky eleven-place amphibian, with two 425 H.P. Wasp engines, taking off.

The plane approached swiftly. It was headed straight toward the boat, at exactly the right height. The instructor surveyed it with appraising eye. This man evidently knew his stuff. All he had to do now was to swerve out a little to clear the boat, and it would be a beautiful shot. Hardly fifty feet away.

But he ought to be turning out now. Just a slight turn to right or left, to clear the boat by a safe margin. Either way, it didn't make any difference. But he'd have to turn. He wasn't high enough to go over the boat. His glide would just reach it.

The instructor's lethargy had been steadily diminishing. Now the last trace of it vanished abruptly. For a certain doubt had assailed him. Eyeing the plane uneasily, he sidled over to the gunwale. This man was getting too close for comfort. What was the matter with him anyway? Did he think he had to scrape the paint off the boat with his wing-tip? He had two hundred feet of room. Why didn't he get over there?

The plane loomed close. The instructor gauged its course with growing apprehension. The whistle of wind through its wings was rising ominously. The blunt nose of its float was pointed straight at him. Above the float, its four-hundred-pound engine hung poised, an impending battering-ram. It was swooping down at a mile a minute. Almost on top of him now. Too late to turn. The boat lay square in its path. It was going to hit——

With one spring the instructor went over the side. As he did so, his foot slipped and he hit with a jarring thump. Then, as the water closed over his head, he heard the crash. The plane had landed in the boat.

A few moments later he was fished out of the water by a very apologetic student. But he was in no mood for explanations. His report of the shot was marked, in large black letters, unsatisfactory. And the word was underlined three times.

When you come to try precision landings, don't try to be too accurate at first. Precision is difficult to develop. If

you try to force it, you run a definite risk. Not that you would be likely to hurt yourself. But you might crack up the plane. It is better to take it easy at first. Give her the gun whenever you are not absolutely sure of your approach.

Speed is the thing you must watch. Be sure you keep enough of it. And make all your mistakes on the high side. If you find yourself overshooting, you can go on around again. But if you lose your speed and undershoot, you may find your plane on its nose.

A quick shot of the gun just before you land is an excellent idea. It does not extend your glide more than a few feet. And, if you should be squashing a little, it will ease you down and save the strain on the landing gear. A good pilot is always handy with the gun.

It is not a good idea to go into any new fields alone. Stick to the ones your instructor has showed you. Picking out a good field requires more experience than you have had as yet. You might easily crack up. Later on, when you go cross-country, you can start exploring.

If the wind is different in direction, you will have to make an approach different from the instructor's. This may give you a shorter run in the field. If it is much shorter, better not try a landing at all. Also, if there is no wind, remember that the plane will come in faster and need more room. You must make allowance for that.

Never land headed straight toward any large obstacle. If you made a bad landing and had to give her the gun, you might find yourself in an embarrassing situation. In any case, you do not want to stop on many of your landings. Just touch your wheels to the ground, open the throttle and go on.

When you are shooting a mark, remember that the one

important thing is to keep your speed. Never try to glide flat. And never bank steeply except at high speeds. If you miss the mark, you can climb up and take another shot at it. But if you lose your speed, you are through for that day, at least.

Try to develop your judgment of the proper height to cut in for your glide. That is the crucial moment. If you swing in toward the mark at the right instant, you can't miss it.

If you do any side-slipping, keep plenty of speed. Coming out of a slip at low speeds, a plane will squash badly. If you were low, it might hit too soon. And don't slip very steeply yet. A vertical slip is easy enough when you know how to handle it. But it takes some experience first.

Don't forget that the plane lands the same way as it always did. If you get so absorbed in watching the mark that you level off at six feet, you can hardly blame it for acting accordingly. When you get down to the ground, forget the mark and make a good landing.

CHAPTER XVIII

CROSS-COUNTRY FLYING

The student has finished his primary course. Now, at last, he can break away from the routine of flying around the vicinity of the training field and can start off across country. For, once he has learned to make precision landings, he is ready to go into new fields. Cross-country flying is the last thing to be learned in elementary training planes.

Two new factors are now involved which the student must be prepared to meet. The first of these is the necessity for selecting and following a course. The second is the possibility of having to pick out and shoot an emergency field. We shall take these up successively.

There are no barriers in the air. The plane passes over valleys and mountains and rivers and forests with equal ease. The whole sky is a road. But if there are no barriers, neither are there any signposts. And therefore, unless a pilot watches his course, he may end up a hundred miles away from where he wants to go.

The course of a flight may be directed either by following a path over the ground or by using a compass. Over land, the former method is the usual one, since it is simpler and more accurate. However, over unfamiliar territory it is not so easy as might at first be thought. Things look very different from the air. Even when a place is known from the ground, it is quite possible to fly over it without recognizing it. And when it must be located from the map alone, an inexperienced pilot can easily miss it. Get-

ting lost on a cross-country flight is by no means an unusual experience. And once lost, the country below all looks alike. It may even become necessary to land and find out where one is.

But if the student will go at the problem carefully, there is little chance of his losing his way during his cross-country flying. It is necessary only to pick out a suitable course, and then to follow that course. To do this, the first essential is an accurate, detailed map. This must include all cities, large towns, railroads, mountains and lakes, as well as the principal highways. On this map, before the start of the flight, the course is planned.

The first thing to do is to pick out an easily recognizable landmark every ten or fifteen miles. A city or large town is of course unmistakable. A railroad junction or a bridge over a river is almost equally good. Or a lake or an isolated mountain will do nicely. Anything which can be seen from a distance and readily identified will serve the purpose.

Next, some guide must be chosen to steer by from each landmark to the next. A railroad or a river is equally easy to follow. A line of hills will do. Or a concrete road is easily distinguishable if there are no others near by with which to confuse it. In case no such guide is available, a course can be steered by compass.

It is a great help to measure the distance between landmarks. Then, by noting the time each is passed over and doing a little mental arithmetic, the time when the next should be reached can be approximately figured. On the flight this will save unnecessary scanning of the ground and reduce the likelihood of a mistake. It is also well to know the compass direction to fly in case of getting off the course.

The endurance of the plane must, of course, be taken into account in planning a flight. An allowance of at least 25

per cent should always be made to insure safety. That is, if the estimated range of the plane is 400 miles, no flight longer than 300 miles should be planned without an intermediate stop for fuel. This is essential in order to provide for contingencies which may occur—head winds, detours around storms, time lost by getting off the course. And in any case, it is not wise to reach a strange place with only a few pints of fuel left. The airport may not be located at once, and when it is, it should be looked over for a few minutes before landing in it.

Having thus planned his flight before taking off, the student should have little trouble in following the course. On clear days it is not necessary to approach each landmark closely when the direct airline does not run through it. As long as it is seen, that is all that is necessary. But when the visibility is poor, landmarks must be approached more closely to be distinguished.

In case of getting lost, it is usually a good idea to keep going in the same direction with the idea of reaching some recognizable point. For instance, if headed for a town located on a river, flight can be continued until the river is reached. Then a decision can be made as to whether to turn up or down stream. A railroad, coast line or range of mountains will serve similarly to indicate the direction of the destination. And nowadays, more and more towns are painting their names on the tops of buildings for the aviator to read. However, if there seems to be no sure way of locating oneself, a landing can be made to ask the way.

Here is the course of a flight from Pensacola to Mobile, Alabama, and thence to Pascagoula, Mississippi, a route used for cross-country training at Pensacola. After taking off, a compass course of 295 degrees, approximately west-

northwest, is flown for 13 miles to the head of Perdido Bay. The latter is a large body of water easily seen from the air. From here an improved dirt road runs for 21 miles to the town of Loxley. Ordinarily a dirt road is not a good guide. But this happens to be the only improved one in the vicinity and is easily distinguishable. The compass course is 300 degrees, in case the road should be missed. Loxley is a fair-sized place on a railroad running north and south, and is just below a westward jog in the line.

Leaving Loxley, the plane is headed due west for 11 miles to the head of Mobile Bay. Eight more miles of flying along the north shore of the bay will bring it to the city of Mobile. This is the largest city in the vicinity, and cannot be missed.

There are several railroads running out of Mobile. The line to Pascagoula starts out on a bearing of 244 degrees, approximately west-southwest. As long as the right line is picked, it can be followed for 39 miles to Pascagoula. The latter will be recognized as a small city on Mississippi Sound at the mouth of the Pascagoula River.

By planning a flight beforehand in this manner and then following the route carefully, it is comparatively easy to cruise around the country without getting lost. Nowadays, of course, airways are being laid out between all principal cities, marked at frequent intervals to indicate the proper direction. But it is important for the competent pilot to be able to find his way around anywhere with nothing but a good map.

The other new factor for which the student must be prepared is the possibility of having to land in an emergency. A certain amount of time may be available, as in the case of a descent required by storm, fog, exhaustion of fuel due

to strong head winds, or losing the route. Or it may be necessary to come down at once on account of failure of the engine. But, whatever the reason, a field must be selected and a landing made in it.

The first essential is, naturally, a field to land in. And it is up to the pilot to see that there is one within reach. He never knows just when it will be needed, or how little time he will have. An engine almost never stops dead without warning. But the thing is by no means impossible. Hence the careful pilot always makes provision for it. He directs his course so that at least some kind of open space is always within the gliding radius—the maximum distance which the plane could glide with a dead motor. When he first takes off, he picks a field ahead of him and notes its position. As he passes over it, he keeps it in mind. When it drops behind, he picks another one farther ahead, then a third, and so on. Over country where there are few fields, he climbs high enough to keep within gliding distance of the ones that are available. He never flies low over unbroken stretches of forest, rocky ridges, water or anywhere else where a safe landing could not be made. If necessary, in case clouds keep him at a low altitude, he detours around bad country. Thus he always keeps some kind of landing place within reach. It need not be a good field. It need only be big enough and free enough from obstacles so that he could get down to the ground without hitting anything. But he knows such a place is always there. And if the engine stopped dead at any instant, he would lose no time in aimless spiraling. He would turn instantly toward his field.

With the field within reach, the next question is the direction of the landing. The plane must be headed approximately into the wind. The importance of keeping track

of this will be apparent. At the field there may be nothing to indicate it. Hence, if a safe landing is to be made, the pilot must know the direction beforehand.

Of course he looked at the wind-sock when he took off from the home field. But there is no assurance that the

U. S. Navy Photo.

A Twin-engined Flying Boat.
Navy PN-9 patrol seaplane.

wind is going to be from the same direction ten miles along the route. He must watch for every opportunity to check up on it. Smoke from a stationary source, such as a bonfire or a smokestack, is an ideal wind indication, as it is accurate and easily seen. No trail of smoke should ever be overlooked. Flags, weathervanes and windmills are

equally accurate, but harder to see. When there are low, broken clouds drifting before a brisk wind, their shadows on the ground may sometimes be observed. But, whatever means he may use, it is vital for the pilot to keep informed of the wind direction. Making a forced landing in ignorance of it would be a serious matter.

Let us assume now that a pilot has to make an emergency landing with the engine running. This might occur in case a strong head wind has cut the speed of the plane down much below normal. But he does not wait until the engine actually stops. Instead, he starts selecting a field with at least twenty minutes' gas left in the tanks. Ordinarily there will be a number of places available. One of these must be chosen.

The first consideration is, of course, size. The field selected must be large enough to get into without danger of hitting anything. The character of the land around it will have much to do with this. If its boundaries are clear, so that the plane can be brought into it not over ten feet up, a shorter space will be needed than when the approach must be made over high trees, wires or other obstacles. If the length in the direction of the wind is sufficient, the width need be great enough only to allow a safe margin for the wings.

The next question is the character of the ground. A smooth, grassy surface is best, though any kind of fairly firm ground will do. Soft ground is bad, however; the wheels will sink in and the plane will probably turn over on its nose. A very hard surface is likewise undesirable, as the plane will roll too far and is likely to ground-loop. It is also essential that the field be approximately level. In emergency a landing can be made on moderately rising ground, though this is difficult and the plane may be dam-

aged. But it cannot be landed downhill, as it would glide too far and then would not stop rolling before reaching the opposite side of any ordinary field.

If the surface is satisfactory, it must be carefully scanned for obstacles. Small trees, stumps, posts, rocks, stacks of grain and such things would damage the plane if it hit them. Irregularities of the ground—holes, mounds, ditches, soft spots, sharp ridges or ruts of any kind—would be likely to break the landing gear. Tall grass is not objectionable of itself, but may be hiding obstructions of various kinds. A few obstacles may not interfere with a landing provided a path between them can be picked out. But if they are scattered generally through a field, the plane cannot be brought down without damaging it.

When the pilot has decided which of the available fields combines adequate size with the best surface, the next thing is the line of approach. While this must be approximately into the wind, it can be varied a little to one side or the other to secure other advantages. If, for instance, there are scattered trees along the leeward boundary, an opening should if possible be picked where a low approach between them can be made. And the direction of the landing can be shifted to avoid obstacles or to give the longest possible run before reaching the opposite side.

It is an excellent idea, if time permits, to make at least one practice pass at a field before attempting to land in it. Even experienced pilots do this. It gives an idea of just how low and how slow the plane must be brought in to land without overrunning the field. And if any obstacle has been overlooked, or if there is any other unexpected disadvantage, the difficulty will be discovered before it is too late.

When once sure that a field is satisfactory, an approach

is made in the same way as taught by the instructor. The plane is dropped down low and brought in on a straight line. The elevators and the throttle are used sensitively to lose altitude gradually until the right height is reached. Then, as the wheels clear the last obstacle, the throttle is closed and a landing made.

After the student has sufficient experience to try it safely, shooting strange fields is the best kind of practice. With fifty hours solo, it should be all right for him to pick out some fairly large fields and make passes at them. He should be conservative at first, not attempting to enter any smaller fields. And no complete landings should be made. The throttle should be opened the instant the wheels touch. But if he does this occasionally, he will be gaining the most valuable kind of experience. And incidentally, there is more interest in such an exploring expedition than in almost any other kind of flying. Picking out new fields and making passes at them has a fascination even for the veteran pilot.

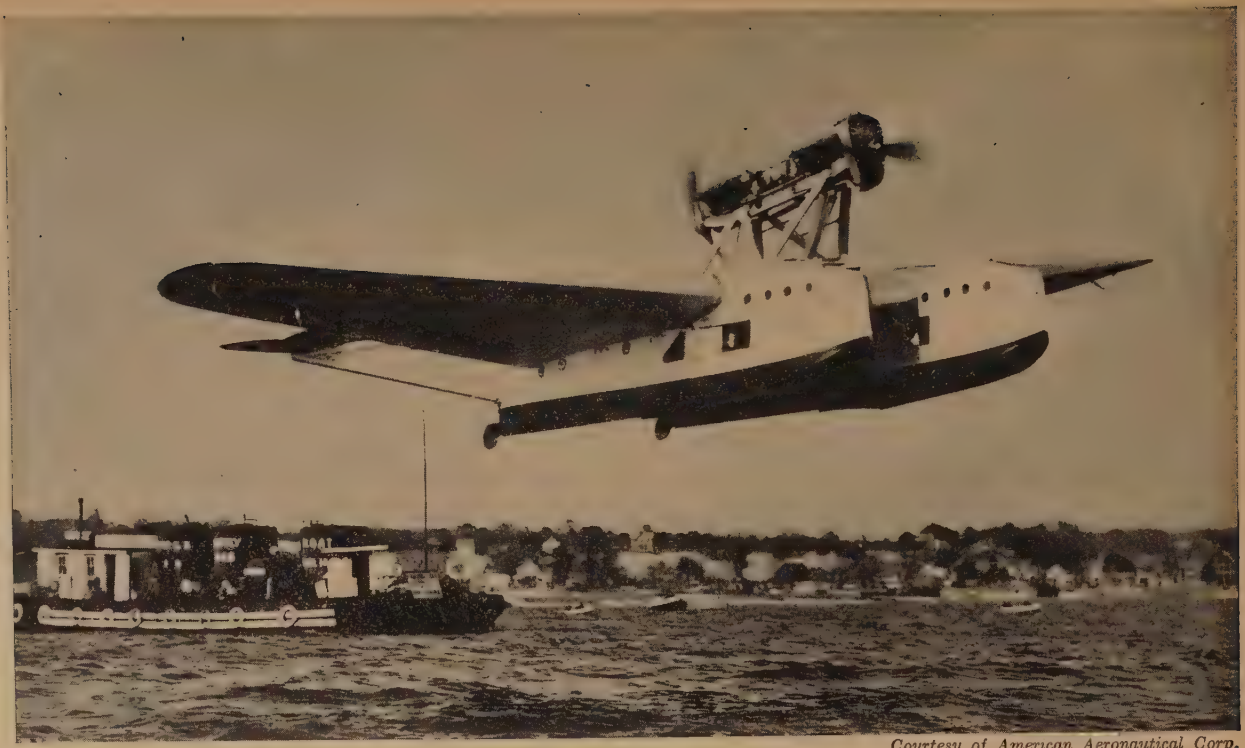
Once in a while, of course, somebody will come to grief doing this. In 1922 three pilots were out on a cross-country hop. They had landed in a number of fields and were on their way home when the leader dropped down to look at a dried river bed. The surface was as smooth as a billiard table, without the slightest obstacle anywhere in sight. It was a perfect landing field—provided it was hard enough. The other two pilots, following the leader down, saw him hesitate. He said afterward that he couldn't make up his mind. But the surface looked dry and firm. There was not a trace of moisture visible. It certainly ought to hold the weight of the plane. So, on an impulse, he cut the gun and leveled off.

The other pilots, having some doubts themselves, watched

the leader closely. The instant his wheels touched, the plane whipped over on its nose. It stopped exactly where it hit, with its tail pointing vertically upward. The surface was a thin dry crust over bottomless muck.

The pilot climbed out and signaled that he was all right. So the other two picked out a small field on higher ground near by and made safe landings in it. After consultation, one of them started back to the air station for a new propeller, while the other stayed there. When he got back, they had gathered a force of half a dozen men. Using boards and lines, they had dragged the plane through the muck to a narrow strip of hard sand at the edge of the river bed. A mechanic put on the new propeller and found the plane otherwise undamaged. The engine ran all right. So the pilot climbed in, gave her the gun and took off with just room enough to spare.

On another occasion a group of five pilots were flying DeHavilands on a trip through Arizona. They were landing at a field near the Mexican border. The surface was hard-baked sand, the runway was long and narrow and they had to land across a brisk wind. The conditions were ideal for ground-looping, and the old DeHavilands were ground-looping ships if there ever were any. The first two pilots stopped safely after liberal use of the throttle to keep their planes from swerving. The third man overshot a little and landed farther down the field than he intended. Using his throttle freely, he rolled along toward the end of the field without losing much speed. After looking out the left side of the cockpit, he shifted his glance momentarily to the right. Square in front of him was a small house. And to his startled gaze, it seemed to be erupting little Mexicans. Children were pouring out of doors and windows and scuttling off like scared rabbits. He even claimed that he saw



Courtesy of American Aeronautical Corp.

A Twin-hull Flying Boat.

Savoia-Marchetti S-55 seventeen-place twin-hull flying boat, with two 518 H.P. Isotta-Fraschini engines in tandem.

one pop out of the chimney. The only way to miss the house was by letting the ship ground-loop. So he kicked opposite rudder and let her spin around. The wing scraped the ground badly but the landing gear, to everybody's surprise, stood the strain. The ship came to a stop with nothing worse than some torn fabric.

Let us now consider the situation when the engine stops. Again the first thing to do is to pick a field. But in this case the choice is more limited. If the engine gives sufficient warning, there may be time to look over a number of places. But it would be dangerous to go down low to examine them. And there may not be much opportunity to look around at all. A field may have to be picked at once.

With the engine dead, a plane will glide a certain distance, depending on its type and load. The average plane will cover at least a mile in horizontal distance for each thousand feet of altitude. Hence from a height of 5000 feet, it could reach any point within a radius of five miles. The pilot will thus have within gliding distance an area of more than 75 square smiles. Anywhere in this he can select a field.

Size is now the one important consideration. The field chosen must be big enough to get into safely. The only real risk involved lies in hitting some obstacle before reaching the ground. If the plane is once leveled off, there is nothing to worry about. It may be damaged by logs or rocks or holes in the ground. But such damage will not be extensive. And pilot and passengers can at worst get nothing more than minor injuries. Hence a large field with a poor surface should always be picked in preference to a small field with better ground but surrounded by obstacles.

The same procedure is followed as in shooting a mark, the leeward edge of the field now being the point of aim. The pilot spirals down toward it in such a way that he can circle around it just as he did around the mark. Then, when he judges he is in the right position, he cuts in toward the field. If he has estimated it accurately, a moderate slip will get him down in the right place. No attention is paid to minor obstacles. The plane is allowed to run into any small trees or fences or posts or other obstructions when they cannot be avoided. The main thing is to drop it on to the ground in a good landing. If it is then damaged, at the worst it can be dismantled and carted home. So long as nobody is hurt, that is all that can be expected.

Practice of cross-country forced landings is vital. At least one flight with the instructor should be devoted to them. And they should be regularly practiced during later solo flying. They are the most rigorous test of a pilot's ability. Training in them is as valuable as any experience he can have. For he can make his mistakes when they do not count. He learns how to select a field from the air, how to pick the best approach, and how to side-slip into it. And if he misses it, he can reopen the throttle and try it again. After a hundred practice passes at various fields, he knows what to look out for. Then, if the engine actually does stop, there is little danger of his making a serious mistake.

Why, then, do serious accidents occur after engine failure? Certainly there is no denying that planes sometimes crash when the motor stops. Every now and then the papers contain an account of a plane which fell while trying to make a forced landing. What is the cause of such accidents?

The cause is invariably the same—neglect of the one

fundamental law of aviation, keep flying speed. It happens somewhat like this. A pilot is cruising along at 3000 feet altitude when a gas line plugs up. In a moment the engine stops. Startled, he noses over and hastily scans the country below. He hasn't been watching it very carefully, and a big field is just beyond gliding distance. He eyes it regretfully, but has to take a smaller field below him. There are trees all around this smaller field. He will have to do some accurate work to get into it. However, he thinks he can make it.

So he spirals down and swings around to leeward of the field. But he gets a little lower than he intended. And perhaps the wind is brisker than he anticipated. So he suddenly realizes that the plane is farther away from the field than it should be. Hastily he swings up into the wind.

Ahead of him are scattered trees. And there is a line of telephone poles along the edge of the field. Unless he reaches it he is going to hit something. And that will mean a wrecked plane. But he should reach it. Without much to spare, perhaps. Still, he ought to make it. He pulls the stick back a trifle to stretch the glide as far as possible. Naturally the air speed drops. But he does not realize it. His attention is fixed on the field. It looks like a good place, smooth and level, with a fine surface for a landing. He must make it. If he can just clear those wires everything will be all right. He pulls the stick back a little more. Again the air speed drops.

The glide is very flat now. But he is unconscious of the danger. His mind is focussed on the field. He must reach it. He is going to reach it. He is just going to clear the wires. Five seconds more and he will be there. He must stretch the glide. He eases the stick back a shade farther—

Just then he runs out of flying speed. Naturally the

plane goes into a spin. The next day you read about it in the papers.

That, in a number of different variations, is the explanation of almost every crash after engine failure. The pilot forgot his air speed. He kept it, but not all the way to the ground. And when you forget that law of flying, there is just one answer. You come down. Keeping flying speed halfway down is no good. Keep your flying speed *all the way to the ground.*

This particular pilot made his first error when he got too far away from the field. But that was not his real mistake. It lost him his chance to save the plane. But he could still have saved himself. An experienced pilot in his place would have recognized the situation and accepted it instantly. Instead of trying vainly to reach the field, he would have picked the clearest space he could see between the trees. Into this he would have spiraled or side-slipped with plenty of speed, getting down as close to the ground as possible before hitting anything. If necessary, he would have side-slipped straight into the ground, hitting wing-first and letting the wing ease the shock as it crumpled up. And then he would have extricated himself from the wreck as philosophically as possible.

A bad crash after engine failure almost invariably means that the pilot was not prepared for emergency. Nothing but rigorous training will enable a man to meet the situation adequately. But such training can be given. And it does produce results. The effects of intensive instruction in forced landings are clearly seen. An instructor was once checking an advanced student in landplanes and, as a regular part of the check, cut the gun on him at 2000 feet altitude. They were beyond reach of any regular field, so the student had to pick an emergency field. The one he

selected was satisfactory. But when he came to shoot it, he got down too low while still headed downwind. He banked sharply in the effort to make it. But his speed was insufficient for a steep spiral, and the instructor had to take the stick to keep out of a spin.

This error he repeated several times. So the instructor sent him back for extra instruction. On completion of this, he went out with him again and this time found his work all right. A week later, on a solo cross-country flight, the student's engine actually stopped. He picked a field of moderate size and shot it. When the plane came to a stop, the extent of the damage was one wing gashed by a post.

Constant practice is the only answer to the threat of engine failure. No pilot can afford to neglect regular drills in forced landings, any more than the captain of a ship can afford to neglect fire and collision drills at sea. If he wants to fly safely, he must be ready to bring his plane down with a dead motor at any instant. A man with 1000 hours in the air who had never made a practice forced landing would be less competent than one with 100 hours who had. When the engine stops, there is no time to learn anything. The result is going to depend on what the pilot already knows. If he is ready for the emergency, if he has a field within reach and has the necessary experience to shoot it, he can get his plane down. He may hit bad ground and crack up after landing. But at least he and his passengers can walk away from it.

CHAPTER XIX

THE PILOT'S LICENSE

EVERY pilot wants a license. If he is going into commercial work, he must have one; while if he is flying for personal purposes, he will want one anyway as a certificate of his competence to handle a plane.

Various kinds of licenses are issued. Students' licenses and private pilots' licenses permit the holders to go up in those capacities. But they can be considered only as authorizations to fly. They do not certify their holders to be competent pilots in the accepted sense of the word. Such a license is useful at the beginning of a flying career. But it should be replaced by a higher one as soon as possible.

In order to be accepted as a certificate of competence, a license must be issued only after certain minimum requirements have been met. The qualifications required by the Department of Commerce for a designation as an industrial pilot are generally considered to be the lowest that can be taken as indicating proved ability. An application for an industrial pilot's license can be made after completion of 50 hours solo. These are the examinations and tests given to applicants:

1. Physical examination.
2. Theoretical and practical examinations in
   (*a*) Air traffic rules.
   (*b*) Elementary engine and plane mechanics and rigging.
   (*c*) Regulations for inspection and operation of aircraft.

3. Practical flight tests in
   (*a*) Take-offs and landings.
   (*b*) Spirals, climbing turns, figure-eight turns, side-slips, stalls.
   (*c*) Precision landings with engine throttled, landing within 200 feet of a mark.
   (*d*) A cross-country flight of 60 miles with two intermediate landings.

An industrial pilot may fly any type of licensed aircraft not carrying persons for hire. That is, he can fly a plane carrying mail or express, or can fly in advertising, photographic, crop-dusting or any other commercial operations. But he cannot fly any plane in interstate commerce which carries paying passengers.

After the same amount of time, 50 hours solo, a license may also be obtained as a limited commercial pilot. The physical, theoretical and practical examinations are stricter than for an industrial pilot. The flight test is the same except that no cross-country flying is required. Such a license entitles the holder to carry passengers within a certain limited area specified in his application.

The highest license issued is the transport pilot's license. Applicants for it must have a minimum of 200 hours solo flying. The course in approved schools for transport pilots includes night flying and the operation of transport planes with capacity of not fewer than four passengers. The same examinations and tests are given as for industrial pilots, and in addition a knowledge of meteorology and air navigation is required. Also, the cross-country flight must extend over a distance of 100 miles.

Transport pilots' licenses are divided into classifications according to the weights and types of planes which the holders are qualified to fly. The first class includes licenses for planes up to 3500 pounds' gross weight, the second for

planes of 3500 to 7000 pounds, and the third for planes of more than 7000 pounds. Under each class there are subclassifications indicating qualifications for flying single-handed or multi-engined planes, open cockpit or cabin planes, and landplanes or seaplanes.

All examinations and tests are conducted under direction

Courtesy of Keystone Aircraft Corp.

A Tri-motored Air Liner.
Keystone Patrician 22-place cabin monoplane with three 525 H.P. Cyclone engines.

of the Aeronautics Branch of the Department of Commerce. Inspectors of this bureau are located in various parts of the country. Detailed information regarding applications can be secured from the Assistant Secretary for Aeronautics.

The federal law regarding licenses applies only to commercial planes flown across state lines. But few air lines

or other commercial operators will consider a man unless he has a transport pilot's license. And some states have already passed laws requiring Department of Commerce licenses from all pilots engaged in commercial operations within their borders. It is likely that more and more states will adopt this provision.

The owner of a private airplane is not required to hold a pilot's certificate in order to fly. But, though he may never expect to carry a paying passenger, a transport license is very much worth having. For he must fly in accordance with exactly the same principles as the pilot of the biggest air liner. Gravity treats him no differently because he is an amateur. He would not go up in a commercial plane with an unqualified pilot. Why go up with himself if he is not qualified? Of course he has to do so while he is learning. But why go on doing it? The requirements of a license are designed for the specific purpose of insuring the holder's ability to take care of a plane in the air. Meeting them is the best way for a man to insure his own safety.

And a license is particularly important for any one who wants to carry passengers. It is no favor to invite a friend up for a ride with you when you don't know how to fly. More than one friend has come to an unhappy end through accepting such an invitation. You may think you are perfectly competent. But the thing to do is to prove it. The least you can do when you invite a man up for a hop is to show him a pilot's license.

When a man gets a license, he should sit down for a minute and think over exactly what it means. The pilot of a plane in the air is in the same position as the captain of a ship at sea. From the instant he starts the engine until he stops it at the end of the flight, he is responsible for its safety and for the safety of his passengers. He must be

prepared to assume that responsibility. And he must have the necessary knowledge and experience to meet any situation which may arise. Once in the air he has no one to depend on but himself. He must use his own judgment. And what he does will determine what happens to the plane.

Suppose we consider the problems of a pilot on a routine trip in an air liner. In the first place, he must know that his plane is in every way ready for the flight. Whether he personally inspects each item or whether he accepts the reports of subordinates is up to him. But, if anything goes wrong, the general manager is not going to go to a mechanic about it. He is going to hold the pilot responsible.

The next thing is the embarkation of passengers. They must be properly directed to their places in the cabin. In case the engines are running, it is imperative that the propellers be roped off or otherwise protected and that some one be specifically charged with the duty of keeping passengers clear of them. People not familiar with planes do not realize the danger from a moving propeller. To allow any passenger to come near one is inexcusable negligence. After all passengers are aboard, doors must be shut and everything secured for flight. The pilot is responsible for seeing that his subordinates carry out all these necessary duties.

In taking off, all applicable air traffic rules and all rules of the airport must be strictly complied with. All safety precautions described in Chapter XI must likewise be remembered. The plane should be taken off as smoothly as possible, and no sharp turn should be necessary close to the ground.

On getting into the air, the plane is swung to its proper course. Keeping the course is then the pilot's most immediate problem. If it is along a regular airway, there will be aids to navigation every few miles. If it is not an estab-

lished route, he must know the landmarks and how to get from one to another. At any instant he must know approximately where he is. Getting lost in an air liner is something that no pilot can afford to have happen to him.

Economy of operation is expected from him by the engineering department. The engines are to be run at the cruising speed specified by standing orders. A safe altitude must of course be maintained, but no fuel should be wasted in climbing unnecessarily high. And proper allowance should be made for wind in order to keep on the direct route. That is, if the course is due west and there is a twenty-mile wind from the north, the plane should not be headed west. If it is, it will be drifted off to southward. Instead, it must be headed enough north of west to offset the effect of the wind. Then it will follow the route closely and reach its destination in the shortest time.

The pilot must know weather conditions. He must be familiar with the latest reports received prior to his departure. And he should know enough about meteorology to estimate the probable conditions ahead of him. Moderately stormy weather need not be avoided, for modern planes are built to ride through almost any kind of air. But it is unwise to fly into a severe storm. And never under any circumstances should an air liner be taken into thick fog. This is the most dangerous menace the weather offers to safe navigation. If the plane has to come down, the pilot cannot see obstacles until he hits them. Serious accidents have been caused by fog. The only safe rule is to avoid it, either by detouring or by landing while obstacles can still be seen.

The pilot is responsible for his readiness to meet the emergency of engine failure. In the previous chapter have been described the essential precautions and the procedure.

Any man who is competent to fly an air liner will be able to make a forced landing safely. He will always choose a course that will not take him over dangerous territory at a low altitude. He will be familiar with emergency fields along the route. He will watch his engines carefully for

Courtesy of Keystone Aircraft Corp.

THE INTERIOR OF AN AIR LINER.
The cabin of the Keystone Patrician.

any sign of trouble. He will know how far he can go with one engine out of commission. And if a motor does fail, he will have the necessary judgment and experience to make a sound decision and carry it out. Whatever happens, he will get his passengers down safely.

No erratic or unnecessarily violent flying is ever to be done in an air liner. The Air Traffic Rules prohibit stunt-

ing when carrying passengers for hire. But the dependable transport pilot goes farther than this. He knows that passengers are frequently unaccustomed to the movements of an airplane. Hence he always tries to fly steadily. He banks moderately and noses over into a glide gently. He never zooms or makes any other needlessly sharp movements of the controls. As far as he can he contributes to the comfort of his passengers by carrying them as smoothly as possible.

When he comes to land, he must again observe all the rules in force at the airport. Needless to say, he makes a smooth landing. And then he is once more responsible for the safety of his passengers during debarkation. Only when they have safely left the field is his responsibility finally discharged.

So, from the time he starts his engines until the flight is over, the pilot's first thoughts are for the safety of his passengers. Every decision he makes, everything he does, is directed toward this end. He will get through to the destination if possible. But if not, he will at least get his passengers down safely.

A pilot carrying passengers as guests in his own private plane is under no legal obligation with regard to their safety. But the moral obligation is the same as that of the pilot of an air liner. It he wants to have a clear conscience, he will accept the same responsibility.

When a man has gotten a pilot's license, he is ready to fly new types of planes. Any type which in general characteristics is similar to a training plane, he can fly at once. But before flying larger craft, he must receive additional instruction. There is nothing essentially new to learn. All airplanes are handled in the same way. But it is necessary

Courtesy of Boeing Airplane Co.

A Night Landing in an Air Liner.

Boeing 80—A twenty-place cabin biplane with three 525 H.P. Hornet engines.

to become familiar with the particular requirements of each new type.

Before flying a new plane, the pilot should first make a thorough inspection of it to become familiar with its structural features. When taking off, he should note the length of the run required, the take-off speed by the air speed meter, and the rate of climb. In the air he will test its maneuverability and performance. Such things should be observed as maximum and minimum speeds, responsiveness to the controls, effect of torque, longitudinal balance and use of the stabilizer adjustment, tendencies in a stall, and other things affecting the handling of the plane. In landing, the length of the glide is important, as are the amount of room required and the stalling speed. The number of hours of instruction required varies with the type, but usually runs from one to five.

Multi-motored planes are similar in flying characteristics to those with one engine so long as all motors are running. In case one engine is stopped, however, the plane is thrown out of balance. That is, if the left engine is stopped, the right engine will tend to swerve the nose to the left. This must be offset by using hard right rudder. If necessary, the nose must be dropped until the required speed can be maintained. A few degrees is enough, and the plane will glide a long distance. But not many twin-motored planes will hold their altitudes on one engine. A tri-motored plane should, however, stay up on two engines.

Turning a multi-motored plane with one engine dead is not difficult. When turning against the running engine—that is, to the right with the right engine running—nearly full rudder must be used. But the plane will then swing steadily. In turning toward the opposite side, the rudder is simply eased and the engine allowed to bring the plane

around. Instruction in flying with one motor is a routine part of all courses in which multi-motored planes are used.

The use of instruments is now permissible, and they will be found of value under certain circumstances. They are particularly important when flying through clouds. When the take-off speed has been determined according to the air speed meter, a speed not less than five miles in excess of this should always be maintained to insure good control.

It will also be found that landings can safely be made crosswind. A side-slip is used to give the plane momentum through the air opposite to the wind. If it is handled skillfully, this momentum will offset the wind drift and permit a landing to be made without side strain on the landing gear.

Night flying is included in a transport pilot's course. No difficulty is encountered in handling the plane in the air. But in landing, lights are required. The moon, even when full, is hardly bright enough to level off by. And unless the lights are brilliant enough to illuminate the ground well, the throttle should be used to ease the plane down in a power landing.

A pilot once went up as observer in the rear cockpit of a DeHaviland to watch the fire of a battery at night. Coming back to the field, there was a line of flares, blazing buckets of gasoline, to land by. On a flight shortly before, he had found them quite satisfactory. By keeping 1000 revolutions, he had been able to make an easy power landing. And he was under the impression that the pilot who was now flying him knew how to land at night. However, as they approached the flares, he became somewhat doubtful of this. Though he couldn't see the ground, he was sure they were too low. He was just about to grab his own stick when the pilot pulled his back. Interfering with the

controls in the dark was risky, and he hoped the nose had been brought up enough. He had only a second to decide, so he let her go. However, he was wrong. They hit with a crack and snapped the axle. Then the plane shot forty feet up into the darkness.

The pilot did the only thing he could do. He held the nose up and eased the plane down with the gun. It hit with a jar and promptly flipped over on its back. As the top of the rudder struck the ground, something carried away and the observer dropped on his face in the dirt. Then the pilot climbed down, and they scrambled hastily out from under the wreck. The observer was much alarmed to find that he could not straighten up. At first he thought something was dislocated. But on investigation he found it was merely the seat. The whole thing had pulled out of the cockpit and was still strapped to him. On unbuckling his safety belt, the difficulty vanished.

CHAPTER XX

SOME SUGGESTIONS TO THE NEW PILOT

You have now learned to fly. And if you want to, you can fly safely. But there is no automatic provision for your safety. It depends absolutely on you. You cannot afford to relax your alertness in any way. The same safety precautions that were impressed on you as a student still hold good. They apply to you just as they do to every other pilot, no matter how many thousand hours in the air he may have. And they apply all the time. If you are careful during 59 minutes of an hour, it may be during the other minute that something happens.

One pilot had that fact thoroughly impressed on him. He had two students out on an instruction flight in an F-5-L, a big twin-motored flying boat carrying a crew of five. There was a brisk onshore wind blowing at the time, and returning planes were swinging in above the hangars in order to spiral down over the beach and land fairly close to shore. When he came in with the first student, the latter failed to make sufficient allowance for the wind. It drifted them down farther than he intended. He realized afterward that it would have been better for him to have taken the controls and swung up sharply. But instead he let the student try to do it. While the latter was getting turned up into the wind, they got beyond gliding distance from the water for about ten seconds. He had to use the engines to get back. As they glided down, the instructor got to think-

ing of what would have happened if those motors had failed them. Of course, there had not been one chance in a million that both of them would stop during that particular ten seconds. But even the possibility of splattering a six-ton flying boat on the roof of a hangar is not a pleasant thing to think about.

They landed and the other student climbed up beside him in the pilot's cockpit. At the end of the hour they came in again. But this time the instructor was ready to see that they did not get beyond gliding distance from water. The student swung in over the hangars. But he had him turn soon enough so that they were not drifted down dangerously far. They flew along just inside the shore line for a few seconds. Then the student reached down to cut the guns for the spiral. As he did so, both engines quit cold.

It turned out afterward that the mechanic, a new man, had gotten mixed up on the gasoline system and let the gravity feed tank run dry. Of course it did not bother them any. They cleared the hangars by a good hundred feet and landed. But all of them did some serious thinking on the question of what would have happened if those engines had stopped during the first approach.

If you are going to fly, you must fly regularly. Once a month is not enough. You must keep your hand in by flying at least once a week and preferably oftener. Otherwise your feel of the air will get rusty. You then run the risk of cracking up on a landing.

Never zoom or chandelle on a take-off. A zoom is executed by holding the nose down with throttle wide open until considerable speed is gained, then pulling the stick sharply back and letting the plane's momentum shoot it upward at a steep angle. A chandelle is the same thing, except that as the stick is pulled back the plane is banked

U. S. Navy Photo.

A squadron of bombers cruising over a city.

steeply in a flipper turn. These maneuvers are perfectly safe at higher altitudes. And they make a spectacular take-off. But in the latter case, if the plane were pulled a little too high, or if the engine happened to stop, the result would probably be disastrous.

An advanced student was once taking off in a DeHaviland from a field on the shore of a bay. To get into the twenty-mile wind which was blowing, he had to head toward a hangar. Then, as soon as he left the ground, the field rules required a left turn out over the water. There was plenty of room to do this safely. But, in a burst of enthusiasm, he decided to show the class something spectacular. So he held the plane down until it had almost reached the hangar. Then he pulled up in a sweeping chandelle. It was a very pretty maneuver. Everybody admired it. But unfortunately he pulled up just a little too high. The plane stalled.

Now a DH which has lost its flying speed drops with the celerity of a rock. And this one did just that. It dived precipitately for the bay. However, the student knew all about stalls. He jammed on opposite rudder and aileron and straightened the ship out. And then he pulled the stick back. The nose started coming up.

But in coming out of the stall, the plane had turned downwind. And it picked up high speed as it dropped. What with the combination of wind and dive, it must have been making at least 120 miles an hour. The student did some fine work in pulling up as fast as he did. He got the nose almost up level. In fact, if it had been low tide he might have gotten away with it. But as it was, the wheels just touched the water.

At 120 miles an hour, it can readily be imagined what happened. The plane vanished in a fountain of spray. The

crash boat shot out from the wet basin, and everybody rushed to the beach. Those nearest plunged in and started to swim out. There was hardly a chance for the pilot. But if he could be gotten out, he might still be breathing.

Then there was a shout. His head had appeared. Two seconds later he emerged with one wheel of the DH under his arm. Its still inflated tire made quite a handy life preserver, with which he proceeded to swim ashore.

Keep away from other planes. The air traffic rules forbid you to come closer than 300 feet. Violation of this provision is a serious offense. It is likely to cost a man his license. And such flying indicates irresponsibility, for it involves a risk of collision, which no pilot has a right to impose on another man.

Never carry a passenger in a cockpit containing a set of controls. He might for some reason become panicstricken and freeze them. Serious accidents have occurred through neglect of this precaution.

In coming down from higher altitudes, you may become aware of an uncomfortable pressure on your ears. If so, swallow occasionally and open your mouth for a breath now and then. This will relieve the pressure. If you want, you can level off and fly along for a few seconds every little while. Coming down thus in a series of short glides will prevent any discomfort until you get used to altitude.

It is risky to fly through clouds in the vicinity of an airport. Somebody else may be doing the same thing and a collision may result. But where there is no danger of meeting any one, it is not difficult. In case of losing control, simply neutralize everything and the plane will presently drop out of the cloud.

Blind flying, in which the course is maintained by means of instruments, is an essential accomplishment for the trans-

port pilot. The air speed meter, turn indicator, inclinometer and compass are the most important instruments. The pilot knows what the speed of the plane in level flight should be for the number of revolutions shown on the tachometer. By maintaining this speed he can fly level, while by cutting it down a little he can climb. In case it increased he would be losing altitude. The altimeter will enable him to check up on this.

In order to hold a straight course, the plane is kept on the desired compass heading. Any swerving from this course will show on the compass card and also on the turn indicator, an instrument whose gyroscopically-driven pointer registers any deviation from straight flight. Lateral balance is checked by means of the inclinometer, a curved glass tube containing liquid and a bubble, similar to a spirit level, which tells when the wings are level.

Blind flying through clouds is not advisable until a pilot has had considerable experience. But in flying on a scheduled route it may sometimes be necessary. Hence you must learn it before taking the pilot's seat in an air liner or mail plane. It involves more strain than ordinary flying, for the instruments must be watched constantly. But an experienced pilot can fly for hours by means of the instruments alone.

Check up on the alignment of your plane. It should balance laterally without any pressure on the stick. If the stabilizer can be adjusted from the cockpit, as is the case in most large planes, you can also balance it fore-and-aft. You then need only keep a little pressure on the rudder. A well-lined-up plane will practically fly itself.

A pilot was one day flying a DeHaviland with a mechanic in the rear cockpit as passenger. The latter knew how to handle a plane, so he let him take the controls for a while.

U. S. Navy Photo.

Fighting planes in line formation.

In a few minutes they hit a slip-stream. It shook them up a little, and the pilot pointed to the receding plane to indicate what it was they had felt. Then he dismissed the incident from his mind.

Presently he noticed that the mechanic seemed to be making a wide circle to the left over the field. He had apparently started turning after they hit the slip-stream. Now he was holding a bank of about ten degrees. His turn seemed to be perfect. At least, no appreciable slips or skids were apparent. The pilot imagined that he had seen something down on the ground below. Possibly somebody had cracked up landing. So he glanced over the side, but saw nothing.

They made a circle of the field in this manner and started another one. By this time the pilot had become rather puzzled. He could see nothing on the ground of interest. So he turned around to find out what the mechanic was looking at. The latter was gazing idly off into the sky. Neither of them had the controls.

When they had hit the slip-stream, the mechanic had thought that it was the stick being shaken. So he had let go of it, under the impression that the pilot was taking control again. The torque, which in that particular ship was rather small, threw it over into a gentle left bank. There it had balanced perfectly, flying itself for a good three minutes before they woke up to what had happened.

This incident suggests another point. Whenever two qualified pilots are flying in a plane with dual controls, one of them must always be designated as first pilot. It is as essential for one man to be pilot of a plane as it is for one man to be captain of a ship. It must be understood that he is in charge and is authorized to take control at any time.

Two students who had completed their training and were

awaiting orders to an operating squadron once went up together in a Jenny. The old Jennies had no stabilizer adjustment and could not be perfectly balanced. With the engine running they were tail-heavy. That is, the tail would tend to sink and the nose to rise, necessitating slight but constant forward pressure on the stick to prevent a stall. One of the students took off, climbed up and started stunting. He was rather proud of his ability to handle a plane and, with the idea of giving the other man a ride that he would remember, he went through every trick he knew. There had been some rivalry between them during the course, and he would have been rather pleased to have the other man say "Enough." He looked back at him once or twice. But, though he looked a little nervous, he refused to do anything but grin.

The first man finished everything he knew. Then he shook the stick and let go of it. He did not, however, hold up his hands.

"Let's see what Bill will do now," he thought to himself. Bill was a pretty good pilot, and he expected to see something in the way of stunts. He was, apparently, not going to be disappointed. The instant he released the stick, the nose started upward. The plane stalled and then fell off, starting a series of wild swoops earthward. It would go careering down in a dive to the left, surge up into another stall and then fall back the opposite way. Its actions bore some resemblance to a falling leaf. But if it was intended for that, it was the wildest one he had ever seen.

"Bill certainly must be anxious to scare me," he thought. But it would never do to look worried. Bill had never said a word while he was doing his stuff. And if Bill could stick with him, he could stick with Bill.

On every swoop they lost altitude. The ground kept get-

ting closer and closer. In spite of himself he began to get nervous. Bill had never done anything like this before. The earth was getting entirely too close for comfort. Finally they got down almost to it. A long swoop barely missed the top of a pine tree.

"Bill has got to come out now," thought the student in

U. S. Navy Photo.

In a close formation.

alarm. He was gripping the seat with both hands, bracing himself. His jaws ached with the strain of clenching his teeth. Bill must have gone crazy. He didn't want to show the white feather. But this was getting dangerous. They hadn't missed the top of that tree by more than twenty feet. If Bill didn't quit now, something was going to happen. But there was the nose going up into another stall——

He made a wild grab for the stick. Bill or no Bill, he had had enough. But he was just too late. The Jenny draped itself in the branches of a pine tree.

The two students presently extricated themselves from the wreck and sat hanging on to the branches.

"For heaven's sake, Bill," the first one expostulated, "you didn't need to crack up trying to scare me."

"What do you mean, I didn't?" demanded Bill. "Weren't you trying to scare me? I didn't have the stick."

Strict regulations are now in force prescribing the manner in which control of a plane shall be changed. The pilot who has been flying cannot consider himself relieved until the other man has acknowledged by a definite signal that he has control. But in any case one man should always be first pilot, in charge of the plane at all times.

Landings at higher altitudes are made at greater speeds than at sea level. The thinner air gives the plane less support and hence its stalling speed is higher. If you make any landings at fields above 1000 feet altitude, you must allow for this. A bigger field is needed, and the plane must be brought in faster. It should not be fully stalled, but instead permitted to go on somewhat hot. After it touches, it will roll farther than at sea level.

A few instances have happened of a wheel's coming off during a take-off, though this is a much rarer occurrence than press accounts would suggest. For some reason or other a landing on one wheel seems to be regarded by the papers as a gamble with death. Superhuman skill is supposed to be needed to get down alive. As a matter of fact, there is nothing particularly dangerous about it. If by some unusual chance it should happen, you simply land with the opposite wing a little low. As the plane loses speed, the axle drops. You will probably go over on your nose, or pos-

sibly even on your back. This will shake you up, and might even break an arm or dislocate a shoulder. But serious injury is unknown.

The day has arrived when safe flying is perfectly feasible. Modern aircraft do not come to pieces in the air. Properly maintained, they will stand anything that may reasonably be asked of them. And modern engines are reliable. They seldom fail, and even when they do they almost invariably give sufficient warning to enable you to reach an emergency field.

Operating standards have risen in proportion. A pilot, to be considered competent, must know how to handle his plane. You can no longer laugh off a crash as an excusable bit of carelessness. Except under unusual and unforeseen circumstances, a wrecked plane means a pilot's mistake. Needless to say, modern operators want only men who can bring their ships home. And if you fly your own plane, as an owner you are equally interested in your own ability as a pilot.

But if you have it in you to fly, if you take a complete course in a responsible school, if you get full value out of every minute in the air, and if you remember the requirements of safety, you can meet the operating standards of to-day. You can qualify for a license as a transport pilot. You can travel the airways of the country from coast to coast. And, when you have had time enough in the air, you can step into the cockpit of the biggest air liner built and take it safely to its destination.

CHAPTER XXI

THE PLANES OF TO-DAY

When the training school is left behind and the newly qualified pilot goes out into the world of aviation, he will find many kinds of airplanes, ranging from tiny moths to huge transports and from slow training craft to meteoric racers, with wing spreads varying from 20 feet to over 100 feet, and weights from 750 pounds to 10 tons or more. The divergent characteristics of these are determined by the particular uses for which they are designed. It will be interesting to look at the different types that are seen in our skies to-day.

Planes are designated as landplanes, seaplanes or amphibians according to the surface from which they are intended to operate. Landplanes and float-type seaplanes we have already seen. Included under the classification of seaplanes are also planes of the flying-boat type, which have hulls instead of fuselages. A hull is a boatlike structure, rounded at the bow and tapering off to the tail. In it are carried crew and cargo, and usually the gas tanks. If it is a monoplane, the hull is suspended beneath the wing, while if a biplane the lower wing projects from either side of the hull. In either case the hull floats directly in the water when the plane is on the surface.

An amphibian is a seaplane equipped with retractable wheels. By lowering these below the float or hull, a landing can be made on the ground. To operate from the water, the wheels are drawn up so that they clear it.

When there is snow on the ground, a plane can be equipped with skis instead of wheels. These long flat pieces of wood enable it to skim along over the surface at high enough speed to take off and land. They are regular equipment for planes operating in Arctic regions.

Planes are of either the open cockpit or cabin type. In the former, pilot and passengers sit in small open cockpits in the fuselage, as in training planes. They cannot ordinarily move around in the air, but must remain in their seats. In cabin planes, the fuselage is built in the form of an enclosed cabin. The pilot usually sits at the forward end. Chairs are provided for passengers, who can move around more or less freely. Windows permit a view of the country below.

Single-motored planes have one engine only, while multi-motored planes have more than one. Most small planes, and many larger ones, are single-motored. The engine is ordinarily placed in the nose of the fuselage. In a flying boat, however, it is necessary to put it between the wings, if a biplane. In the case of a monoplane, it may be either above or below the wing.

In a twin-motored plane, the two engines are ordinarily placed one on either side of the fuselage, between the wings of a biplane or either above or below the wing of a monoplane. Planes have, however, been built with two engines in tandem, that is, one ahead of the other in the center line. A tri-motored plane usually has one engine in the nose and one on each side of the fuselage. A few four-motored planes have been built, having two engines in tandem on either side.

Planes are also designated according to their uses. No hard and fast classification is possible, since many of them are suited to various different purposes. However, there

are certain general types which can be described, and with which it is desirable to be familiar.

Light planes are of small size and comparatively light construction, and are powered with engines of 30 to 50 H.P. They carry at most two people, and frequently only the pilot. Their speeds are low in comparison with standard-sized craft, the maximum being usually not over 75 miles an hour. Landing speeds are also low. The fuel supply is limited to about three hours. No load other than fuel and crew can be carried. Such planes are designed primarily for sport use by the amateur pilot.

We are already familiar with training craft of the open-cockpit type, of 30 to 40 feet wing span and powered with engines of 60 to 200 H.P. A wide variety of planes similar in construction are employed in general utility work. Their uses include sightseeing flights, aerial taxi trips, newspaper and express delivery, photography, advertising, spraying and dusting, forestry patrol and other services. The commercial purposes for which planes can be effectively utilized are constantly increasing in number. And for the private owner a small open-cockpit plane is the ideal type for sport flying.

The Alexander Eaglerock A-2 is a typical open-cockpit biplane in this class. Its length is 24 feet, its wing span 36 feet and its gross weight loaded 2442 pounds. Its 90 H.P. Curtiss OX-5 engine, an eight-cylinder water-cooled model, gives it a high speed of 100 miles per hour and a cruising speed of 80 miles. The landing speed is 38 miles. It carries a pilot and two passengers, and has a maximum cruising radius of 850 miles. The Eaglerock A-1 is a similar plane powered with a Wright Whirlwind 9-cylinder, 220 H.P. radial engine, which gives it a high speed of 130 miles and a cruising speed of 110 miles.

Other typical planes are the Travelair and Waco open-cockpit biplanes. The former is a three-seater with a length of 24 feet and a wing span of 34 feet. A choice of power plants is offered, including a Kinner 90 H.P., 5-cylinder radial; a Warner Scarab 110 H.P., 7-cylinder radial; an Axelson 115 H.P., 7-cylinder radial; and a Curtiss Challenger 170 H.P., 6-cylinder radial. With these various engines the maximum speeds range from 105 up to 126 miles per hour, with cruising speeds in proportion.

The Waco is also a three-place plane, with a length of 23 feet and a wing span of 30 feet. It can be equipped with various different engines developing from 90 to 220 H.P. With these its speed ranges from 96 up to 135 miles per hour. Any of these three planes or others of similar design can be used equally well for training, general utility and sport flying.

Mail has been carried in many different kinds of planes, since almost any type can be pressed into this service. But planes designed for this particular purpose are now coming into increasing use. Carrying capacity and fairly high speed are the requirements. One design used on the transcontinental run, the Boeing 40-B2, is a biplane with a length of 33 feet and a wing spread of 44 feet. It is powered with a Pratt and Whitney Hornet 525 H.P. nine-cylinder radial engine, and will cruise at 120 miles an hour carrying a load of 1400 pounds. The mail is stowed in compartments in the fuselage, in which is also a small cabin for two passengers. Behind this is a single open cockpit for the pilot.

Cabin planes, seating from three to six persons, are being built in various models as private air cruisers. The monoplane type, with an engine of 100 to 300 H.P., seems to have been widely adopted for this purpose. In the enclosed

Courtesy of Maddux Air Lines.

A Fleet of Air Liners.

Twelve tri-motored Ford monoplanes of the Maddux Air Lines at the Grand Central Air Terminal, Glendale, Calif.

cabin, guests can sit comfortably in wicker or upholstered chairs, protected from the wind. Windows permit the enjoyment of the landscape below, while the noise of the engine is diminished sufficiently to permit conversation.

The Curtiss Robin is a typical small-cabin plane. It is a monoplane with a length of 26 feet and a wing span of 41 feet. In an enclosed cabin beneath the wing are seats for the pilot and two passengers. Equipped with a Curtiss OX-5 90 H.P. engine, it has a high speed of 100 miles per hour and a cruising speed of 85 miles. At the latter rate, it carries enough fuel for a flight of 600 miles. When powered with a Challenger engine of 170 H.P., its maximum speed is increased to 120 miles per hour.

The Stearman Cabin-1 is a biplane model for the private owner. In its enclosed cabin between the wings are seats for four people, including the pilot. A Wright Whirlwind engine of 300 H.P. gives it a high speed of 135 miles per hour.

The Ryan Brougham is a six-place cabin cruiser of the monoplane type, similar in design to Lindbergh's transatlantic plane. With a Whirlwind engine its high speed is 140 miles per hour. It can be either furnished as a landplane or equipped with floats for use as a seaplane. The Bellanca CH-300 is likewise a six-place cabin monoplane powered with a 300 H.P. engine.

A small amphibian cabin plane is offered in the Loening Commuter. This is a flying boat with an enclosed cabin accommodating the pilot and three passengers. Its retractable wheels can be lowered for a landing on a flying field or raised to operate from water. A Whirlwind engine gives it a high speed of 116 miles per hour.

Larger single-engined cabin planes are built both for private use and for operation on air lines. The Fairchild 71

is a representative craft of this type. It is a monoplane with a length of 32 feet and a wing span of 50 feet, having accommodations for a pilot and six passengers. Its gross weight loaded is 5500 pounds. A Pratt and Whitney 425 H.P. Wasp engine gives it a high speed of 138 miles per hour, while at a cruising speed of 110 miles an hour it can cover 900 miles. Either floats or skis can be readily substituted in place of wheels for operation over water or snow.

The Lockhead Air Express is a monoplane designed especially for high speed. With a pay load of 1200 pounds, either passengers or express, its Wasp engine will pull it along at a maximum rate of 180 miles an hour. At a cruising speed of 150 miles it will cover a distance of 700 miles.

Eight-place amphibian cabin planes are built by Fokker and Loening. The former is a monoplane powered with a Hornet 525 H.P. engine, which has a speed of 125 miles an hour. The latter is a biplane, whose speed with a 525 H.P. Wright Cyclone engine is 130 miles.

Multi-motored air liners, carrying from eight to thirty passengers, are being built in increasing numbers to meet the growing demand for air transportation. The majority of these are powered with three engines. The Ford 4AT-E is a typical tri-motored transport monoplane. It has a length of 50 feet and a wing span of 74 feet, and is constructed entirely of metal. It can carry a pay load of 1725 pounds and weighs, fully loaded, 10,000 pounds. The cockpit is equipped with dual controls and has seats for two pilots. In the cabin are accommodations for 12 passengers. Three Wright Whirlwind 300 H.P. engines give a maximum speed of 130 miles per hour, while at a cruising speed of 110 miles the plane has a radius of 560 miles.

The Boeing 80-A is a large transport biplane. It is powered with three 525 H.P. Hornet engines, and has places

for two pilots and 18 passengers. The Keystone Patrician, a monoplane, carries 20 passengers. With its three 525 H.P. Cyclone engines, it has a speed of 150 miles an hour.

The largest plane in America is the Fokker F-32 four-

Courtesy of Maddux Air Lines.

THE TAKE-OFF OF AN AIR LINER.
Tri-motored Ford monoplane of the Maddux Air Lines taking off at Glendale.

engined monoplane. First flown in the fall of 1929, it is designed to carry 32 passengers and a crew of four. This plane is 70 feet long and has a wing spread of 99 feet. It weighs empty 13,800 pounds and can carry a useful load of 8000 pounds, a total weight of eleven tons. Its four

engines are grouped two in tandem on either side of the fuselage, beneath the wing. They are of 525 H.P. each, giving the plane a total propelling force of 2100 horsepower. With all motors running at full power, the plane makes better than 150 miles per hour. It will cruise on two engines at 120 miles per hour, while the landing speed is only 47 miles per hour. The crew consists of two pilots, a radio operator and a steward. For night flying, the plane can be equipped with berths for 16 passengers.

In the fall of 1929, regularly scheduled trips were being made by passenger liners over more than 25,000 miles of airways in North America. Routes extended from the Atlantic to the Pacific and from Canada to Panama. The average scheduled speed was 85 miles an hour, while fares averaged 12 cents a mile. Over some of the faster lines speeds in excess of 100 miles an hour were being maintained. And fares as low as nine cents a mile were advertised. Transcontinental service in conjunction with railroads was established during July of this year.

A naval aviator who had never flown as a passenger in a cabin plane recently took his first trip on an air liner. Having to come down from Los Angeles to San Diego, he made a reservation on a plane of the Maddux Air Lines. In order to see how passenger traffic was handled, he took an earlier bus out to the field. His account of his trip begins with the automobile ride from the city ticket office in the center of Los Angeles to the Grand Central Air Terminal at Glendale.

"After a thirty-minute ride, we draw up before a large stone building, with red-tiled roof, which might be a railroad station if it were not for the wind-sock swaying above it. It is so new that, from its north end, there comes the staccato tapping of a riveting hammer on unfinished steel

work. Inside, well lighted by high arching windows, is the waiting room. To the right are signs indicating the ticket office and baggage room. On the left, a small cabin plane is on exhibition. Traffic men in blue uniforms and white caps direct passengers, while a red-capped porter hustles baggage around.

"At the opposite side is the entrance to the concrete field platform. This platform is enclosed by a green-painted steel fence, through which projects a covered passageway, like a steamship gangway planted in the cement. Its inner end is closed by gates, above which is a sign 'Passengers only.' Beyond the fence is a concrete runway for planes, and beyond this the expanse of the field, a good half-mile long and several hundred yards wide.

"On the platform passengers wait, talking or reading the bulletin boards announcing arrivals and departures of planes. Presently they turn as a ship appears in the northern sky. It grows rapidly larger, its spreading single wing and three engines revealing it as an incoming air liner. It skims in over the edge of the field and drops to the ground. The pilot makes a smooth landing and, braking the wheels skillfully, brings it to a stop. It is the down plane from San Francisco, a big ten-passenger Ford monoplane.

"The plane swings around and heads for the station runway. On this, two white lines run parallel to the platform. Bringing his wheels on to these, the pilot guides his plane up to the covered passageway, over the top of which its high wing passes. Just beyond is a cross line, where he brings the wheels to a stop. From the end of the passageway a telescoping section slides out on a track to the door of the plane. No risk is taken of permitting passengers to approach the propellers. As they disembark, they are automatically guided to the platform. Following them comes

their baggage in the hands of the porter, to be put into the cars which wait to carry them into the city.

"Its passengers discharged, the plane's engines speed up again. It turns and taxies down to the hangars at the south end of the terminal, to join a little flock of its sister ships which are gassing after flights or being groomed for coming runs. Presently the engines of one of these planes are started. After a few minutes of warming up, they are tested out. Their smooth, even drone is satisfactory, and the plane is ready to go. It starts forward and comes rolling up the runway. The announcer calls out 'San Diego and Agua Caliente,' and passengers cluster around the gate. As the plane comes to a stop, baggage is run out on a truck, put aboard and stowed aft in the tail. Then the gate is opened. A gateman examines tickets, checking them off on a passenger list. Passengers walk through the passageway, step on the porter's foot-stand and up into the plane. Then the door is shut. The Chief Dispatcher signals the pilot and the latter opens his throttles to taxi down to the end of the field.

"Meanwhile a second plane has come up and is waiting with engines idling. The trip is being made in two sections to-day to take care of all the reservations which have been made. While it is taking its passengers aboard, the first plane has reached the northern end of the field and swung around on to the concrete take-off runway. A signalman steps out and scans the sky. No other planes are approaching, so he holds up a white flag. The idling propellers thin to sheer disks as the throttles are opened. The plane starts forward, slowly at first but quickly gathering speed. Its wheels lift from the concrete and skim along just above it for a moment. Then it starts a steady climb. In a few moments it is a dot in the southern sky.

"My reservation is for a later plane, and as I wait ships come and go. A small open-cockpit biplane comes in, lands and goes over to the hangars. A cabin monoplane with bright orange body and yellow wings takes off with two passengers on a private trip. A small, fast single-engined liner comes in with passangers from Nevada. A tri-motored monoplane of a different line arrives from San Diego. A Ford plane takes aboard ten passengers for a sightseeing tour over Los Angeles and the nearby beaches. Another one comes in from Bakersfield. And presently a Ford with three big 425 H.P. Wasp engines taxies up for the 3:00 P.M. run to San Francisco. The terminal is as busy as a railroad station.

"Five minutes before its scheduled time of departure, the San Diego plane on which I have a reservation comes rolling up from the hangars. Its three 220 H.P. Whirlwind engines are turning smoothly. Its skin of corrugated duralumin reflects the afternoon sun with a soft gray glitter. In the leading edge of the thick wing, one on each side, are two searchlights for night flying. Behind the center engine, in the nose of the fuselage, is the glass-enclosed pilot's cockpit. Back of it, underneath the wing, are the windows of the cabin. The broad rubber-tired wheels follow the white lines exactly, coming to a stop in the designated spot. The door, at the rear end of the cabin, is opened and our baggage is put aboard.

"The pilot, seated at the controls, wears a blue uniform with two gold bands on each sleeve and a pair of gold wings on the left breast. His white cap bears, in gold letters, the word 'captain.' His assistant, who is waiting to superintend the embarkation of passengers, wears a similar uniform except that his sleeves have only one gold stripe and his cap carries the designation 'mate.'

Courtesy of Maddux Air Lines.

DOWN THE CALIFORNIA COAST.
A Maddux liner en route from Los Angeles to San Diego.

"The gates swing open and, after examination of our tickets, we get aboard. There is a capacity load of ten passengers. We seat ourselves and the assistant pilot closes the cabin door. Then he goes forward and up through a small door into the cockpit, where he seats himself beside the pilot.

"The dispatcher raises his hand in signal and the pilot opens the throttles slightly. Under the pull of the propellers the plane starts down the runway. At the end of the field he swings around on to the take-off runway. There he stops and tests out the engines one at a time, first left, then center, then right, holding the plane with the brakes as he does so. They are all running right. We are ready to go.

"The signalman raises the white flag. The pilot pushes the throttles open and the engines respond with a rush of power. The wheels start rolling along the concrete. I look down at the left wheel whirling faster and faster over the smooth surface. The tail is up now, and in a few seconds we pass the station. Another moment and I see the wheel lift clear. It goes on spinning idly with decreasing momentum as we mount.

"The air port drops away while we steadily gain altitude. To right and left are mountains enclosing the valley in which the field is situated. Ahead we see the buildings of Los Angeles. The plane sways a little in currents disturbed by the nearer ridges, but the air is not rough.

"The interior of the cabin is finished in gray leather. The chairs, in which one can lean back comfortably, are of wicker with brown leather cushions. There are five on the left side and three on the right, with an aisle between. Across the door a longitudinal seat has been dropped which accommodates two people. Alongside each chair is a win-

dow, one panel of which can be slid open. There are small individual ash receivers, as well as lights above each seat. On the forward wall of the cabin is an altimeter whose needle is reading 1000 feet. Near it is the Department of Commerce license of the plane. On the cockpit door are the names of the pilot and his assistant. On the rear wall is a board, which may be used for writing letters on the stationery provided in holders. Each sheet, below the name of the line, bears the heading 'In flight between.' A pair of field glasses for the use of passengers hangs from a hook. And through a door is the lavatory in the tail.

"The mate opens the cockpit door and comes back to collect tickets. The noise is not at all bad. It is about the same as in a railroad train traveling at good speed. You must raise your voice to be heard. But when you do, conversation can be carried on without difficulty. The mate says that the engines are turning up 1650 revolutions and that we are making 90 miles an hour. We are just crossing the eastern end of Los Angeles, and through the windows he points out parts of it to the lady in blue who is occupying the longitudinal seat with her husband. This is her first flight, and she is much interested.

"We have left the city behind now, and are over the groves of trees in Orange County. They look like green dots set in hundreds of regular rows. Here and there are houses, close to intersecting dark lines which mark highways. The specks crawling along the latter are automobiles. The altimeter reads 2000 feet, and it is cooler. The air is perfectly smooth, without a suggestion of a bump. There is little vibration, hardly as much as there would be in a train. The girl in white sitting opposite me lights a cigarette.

"It is hazy this afternoon, but presently we see the coast-

line to westward. There are clouds out to seaward, white in the sun. The young chap sitting behind me asks me the name of the place on the coast we are passing. I can just distinguish it as Newport Beach. This is his first trip over the route, he says. But he is familiar with other lines, both here and in Europe. And I discover that he once went up for a stunt hop with a pilot out in Honolulu who is a friend of mine.

"We reach 3000 feet altitude. Here the haze ceases abruptly. It is sliced off seemingly as level as the surface of the sea, a usual phenomenon of the California coast. To eastward, mountains rise out of it like islands. They stretch away, peak beyond peak, as far as the eye can reach. We are almost on a level with the nearer ones. But blue in the distance are outlines that tower thousands of feet higher.

"We are passing Capistrano now, and below us are bare brown hills. Between them run arroyos, like crinkles in a carpet. Those clusters of brown pin-points are herds of cattle grazing on the sunburned vegetation. We are nearer the coast, and wisps of white cloud are drifting like dust rolls across the earth. The lady in blue has started writing a letter. Though this is her first trip, she seems quite at ease here. She is not in the least nervous, she says. Some of her family had tried to dissuade her with the threat of air-sickness. But she is not feeling the slightest suggestion of it. Nor are any of the other passengers, so far as I can tell.

"We are about off Oceanside, I believe. But the clouds are so thick that I can catch only occasional glimpses of water below us. To westward they are unbroken, white as an Arctic snowfield in the sun. Their glinting shoulders and shaded valleys stretch to the horizon. Our shadow

travels along over them, inside the circular rainbow which a plane always throws on sunlit clouds.

"The engines have been keeping up their steady drone for over an hour, my watch tells me. We should be about over La Jolla. Suddenly the drone dies down and the plane tilts forward. The lady in blue looks up inquiringly. I explain that we are nearly there, and that the pilot is going down through a hole in the clouds ahead of us. She nods in understanding. In a few seconds the sun is cut off as we drop, our wing tips brushing misty shoulders on either side. Then the earth appears, San Diego, its bay, Point Loma and to westward the Pacific.

"The pilot reopens the throttles and the engines pick up. It seems gloomy here after the brightness above. Only in one spot is there light. Far out to sea, through a rift in the clouds, the sun's rays have turned a patch of ocean into a lake of copper light glowing like an ingot in the dusk. But we are too busy to do more than glance at it. The airport is just ahead. In a few minutes the pilot banks and starts a circle to leeward of it. We gather up our things as he eases the throttles back for the final glide. The earth comes up rapidly. Houses, factories, streets slip under us as we spiral in over the shore of the bay. Then the smooth surface of the field flows beneath our wheels. They touch gently, starting into sudden life as the weight of the plane settles on them, only to slow down quickly under the restraint of the brakes. The pilot taxies over to the field platform. Then the motors relapse into idleness and the mate comes back to open the door. In an hour and a quarter we have covered 110 miles with as little concern as if we were on a railroad train taking three times as long."

CHAPTER XXII

AVIATION IN THE ARMY AND NAVY

The Army and Navy have many different types of aircraft to meet their various needs. Combatant planes are classified according to the following purposes: fighting, light bombing, torpedo and heavy bombing, attack, observation, scouting and patrol. In addition there are training, transport, utility, ambulance and experimental planes.

Practically all combatant craft are biplanes, designed to stand the stresses involved in rapid maneuvering at high speed. Fighting planes are small, fast single-seaters built for aerial combat work. A typical fighter has a wing spread of 30 feet, weighs 2800 pounds and is powered with a 425 H.P. radial engine. It can make 160 miles an hour in straight flight, and will stand diving at a velocity of 300 miles an hour. Its armament consists of two machine guns set in the fuselage and firing through the propeller. By means of a synchronizing mechanism, the bullets are fired between the revolving blades. A sight is mounted on the cowling in front of the pilot. The guns are then aimed by maneuvering the entire plane. The function of the fighter lies in attacking other aircraft in flight.

Planes of this same type may be used for light bombing. Carrying bombs weighing from 20 to 50 pounds, they can dive on an objective and release their loads just above it. Their high speed makes them difficult to hit with anti-aircraft fire.

Heavy bombing planes are built to carry large loads. A typical single-engined bomber has a swing spread of 50 feet, weighs 6000 pounds and is powered with a 525 H.P. engine. It can carry a 1000-pound bomb for a distance of 500 miles,

U. S. Navy Photo.

An Aerial Combat.
A fighting plane attacking a bomber.

release it and return to its base. A huge twin-engined plane, with a wing span of 75 feet and weighing over six tons, can carry 2500 pounds over the same distance, or 1000 pounds over a correspondingly greater radius. For

naval work, a torpedo may be carried instead. This is dropped into the water from a height of about ten feet. It then sets out on a run toward its objective in the same manner as a torpedo fired from a ship. In addition to their loads, bombers usually carry several machine guns, mounted in such a way that they can be swung freely, in order to defend themselves against fighting planes.

An attack plane carries a battery of machine guns mounted to shoot downward. Its function is to attack ground positions. Cruising at low altitudes, it can sweep a wide area with its fire.

Observation planes, of moderate size, power and speed, are equipped with radio sets to permit communication with ground stations or ships. Circling above a position at 10,000 feet altitude, they can watch the fire of heavy guns and report their observations by radio. By this means the aim of the guns can be corrected until the shells reach the target. They can also detect and report tactical maneuvers of opposing forces.

Naval scouting planes are similar in type to observation planes. Their function is, however, different. They scout ahead of a fleet to search out enemy forces within a radius of several hundred miles. Any ships sighted are reported by radio. Both observation and scouting planes usually carry machine guns for defensive purposes. But they would not ordinarily be used offensively.

Patrol planes are large flying boats, usually of the twin-motored type. They operate from shore bases to patrol the waters adjacent to the coast line, up to a maximum distance of 750 miles. They are equipped with powerful radio sets, with which they can report any hostile ships that they sight. They would also normally carry several bombs of 50 to 100 pounds' weight for use against submarines.

And they are well armed with machine guns to defend themselves.

In modern tactics, planes no longer operate singly. They always cruise in sections, divisions or squadrons. Hence formation flying, involving maintenance of position in relation to a leader and shifts from one formation to another,

U. S. Navy Photo.

A Take-off from a Carrier.
A fighting plane leaving the deck of the U.S.S. *Saratoga.*

is an important part of the training of a military or naval aviator. And the efficiency of any air force will depend on the ability of its pilots to maneuver and attack by squadrons rather than individually.

At the beginning of 1929 the Army possessed 1100 planes, of which 750 were of combatant types. These planes are stationed at various fields in the United States, Hawaii and

Panama. Maneuvers are carried on regularly, during which practice is obtained in gunnery, bombing and observation work.

At the same time the Navy had 1000 planes, of which 735 were suitable for combatant use. Some of these are based on shore stations for coast defense work. But strong forces are assigned to the Fleet. It is not ordinarily possible, however, for planes to take off from the surface of the sea on account of the waves. Hence fleet aircraft operate from carriers and catapults. Landplanes are flown from the former and seaplanes from the latter. Their performances in maneuvers at sea indicate that they will be an important factor in all future calculations of naval strength.

The Navy possesses two large aircraft carriers, the *Saratoga* and the *Lexington*. These are huge vessels of 35,000 tons displacement, capable of speeds up to 34 knots. Each one can operate more than 75 planes at a time, besides carrying additional planes in storage. There is also the experimental carrier *Langley*, a converted collier on which present methods of carrier operation were developed.

The *Saratoga* and the *Lexington* each carry four squadrons of planes: a scouting squadron, a light bombing squadron, a torpedo and bombing squadron and a fighting squadron. The mission of the first of these is to search ahead of the Fleet for hostile forces and report their position by radio. They can then be attacked by the bombing squadrons. The light bombers can operate against small vessels, or can damage the upper works of large vessels. The heavy bombers are designed to attack capital ships with large bombs or torpedoes. In case any hostile aircraft appear, it is the mission of the fighters to repulse them.

All battleships and light cruisers carry observation planes on catapults. From these they can be fired into the air.

U. S. Navy Photo.

On the deck of a carrier.

They can then climb up as high as necessary above hostile forces. Here they observe and report by radio the movements of opposing vessels and the fall of shells near them. In target practice it is found that airplane observers can correct or "spot" the fire of ships' guns with great accuracy. On conclusion of the practice they land on the water near the ships. They then taxi up alongside, where they are picked up and hoisted aboard once more.

Being fired from the catapult of a battleship is decidedly a unique experience the first time you try it. A catapult is a long, girder-like structure along which a car, carrying the plane, can slide. Different types have been built, varying in length from 45 to 60 feet. Some are fired by compressed air, while in others a charge of smokeless powder is used as a propelling force. One catapult on a battleship is mounted on a turntable set in the deck at the extreme stern of the ship. Another is built on top of one of the turrets. They can be rotated until they are headed over either side, so that planes can always be fired into the wind.

On the top of the catapult is a greased track, along which the catapult car runs. By means of sheaves and a cable, the car can be pulled quickly along the rails. It is set at one end of the catapult, with the plane resting on it. The engine of the latter is started and warmed up. Then, when the pilot is ready, the catapult is fired. The cable pulls the car down the track at a rapidly increasing rate. It goes from rest to a speed of 55 miles an hour in a little over two seconds. At the end of the track the car is stopped, catapulting the plane into the air.

When you are going to go off a catapult, the first thing is, of course, to inspect the mechanism. The plane must have adequate speed as it leaves the car or it will fall into

U. S. Navy Photo.

CATAPULTING A PLANE FROM A BATTLESHIP.
An observation plane leaving the catapult of the U.S.S. *New Mexico.*

the water. Hence everything must be in perfect working order. Also, the plane must be properly set on the car, seated firmly on it but free to leave it when it reaches the end of the track. And its landing-gear brace-wires must be taut, with turnbuckles safety-wired.

When satisfied with the adjustment of the catapult, you climb into the cockpit and start the engine. It must then be well warmed up, for it needs to be running at full power when the plane is fired. Everything in the plane must be tightly in place. A pyrene loose in its rack would be likely to ram you in the ribs if you did not secure it properly. And the observer in the rear cockpit must see that the radio set is clamped in its box unless he wants to get it in his lap. Then the catapult is rotated or "trained" until the plane is headed out over the side and as nearly as possible into the wind.

With the ship under way, catapulting is controlled from the bridge. So you sit and watch a signalman. Presently he holds up a red flag. That means stand by to catapult. You try out your engine once more, noting the gauges critically. Everything seems to be all right. So you lean out of the cockpit and signal to the catapult officer. This is a powder catapult, up on top of the after high turret. And at your signal, you see him tap the shoulder of a gunner's mate, kneeling beside the track. The gunner's mate picks up a charge of smokeless powder and rams it home in the chamber of the catapult gun. Then he swings the breech plug into place and locks it. The catapult is loaded.

You wait a minute or two longer, one hand on the stick and the other on the throttle. The signalman is still holding up the red flag. He is looking up at the bridge, waiting for the order of execution. There the Officer of the Deck

is watching the flagship, at the head of the column, for the signal which will send planes shooting into the air from every battleship. Suddenly it comes. At the word of command, the signalman drops the red flag. Then you see him raise a green one. Catapult.

You shove the throttle all the way forward. The engine roars out in response. You take a final quick look at the tachometer. It registers 1700 revolutions—plenty. You thrust your arm straight out and hold it for a moment. Ready. Then you draw it in. Fire.

You sit relaxed, head leaning slightly forward. Your right hand grips the stick, braced by your elbow resting against your hip. The stick shakes as the propeller blast, whipped past you at a mile a minute, beats on the elevators. The plane trembles, straining at the cables which hold it in leash. Ahead, through the windshield, you have a glimpse of the water sliding past at fifteen knots as the ship forges along in column. It is forty feet below. On the left side you can see a little corner of the gray top of the steel turret on which you are sitting. And out of the corners of your eyes you are aware, on one side, of the mast, on the other, of men standing on the quarterdeck, faces upturned watching the plane.

Suddenly you start forward. It feels as if something had grabbed you up and were carrying you away. You are pressed back against your seat. Your head is thrown backward. You cannot move arm or leg. You are, for the moment, immobile. Yet there is nothing uncomfortable about it, no shock or jerk or snap. Simply smooth, even, irresistible pressure. Like an elevator turned horizontally and magnified five times over. There is not the slightest tendency to become dazed. You are perfectly aware of the mast flashing past you, of the turret sliding out from under

you. You do not even try to brace yourself. You simply sit relaxed and let yourself go.

It lasts for two seconds. Suddenly the pressure ceases. You are in the air, and instinctively you fly. The bang of the catapult gun follows faintly through the roar of the engine. The plane is dipping a trifle. But the pull of the propeller picks you up, and the stick in your hand becomes firm as the air flow closes around the elevators. The nose responds to your touch. The plane is under control. You glance back at the receding ship, forging along in her place in column. Then you ease the stick back and start to climb.

After two or three shots, you get quite used to it. Going off a catapult becomes mere routine. The action of the mechanism is simple and positive. It is almost impossible for anything to go wrong, and even then nothing more than damage to the plane would occur. No one has ever been seriously hurt catapulting from an American warship.

CHAPTER XXIII

THE AVIATION OF THE FUTURE

In the twenty-six years since the first brief flight of the Wrights, the capacities of aircraft have increased enormously. A United States Navy plane has climbed to an altitude of 39,140 feet, over seven miles. A British racer flew at a speed of 355 miles an hour, nearly six miles a minute. A French plane covered 6158 miles, from Paris to Manchuria, in a single flight. A German plane took off with a load of gas which, without refueling, kept it in the air for 65 hours. While an American plane, refueled daily, remained aloft for 420 hours, more than seventeen days.

These are the records as they stand in the fall of 1929. But that they will remain at these figures for any length of time is not to be expected. The end of this year may see some of them exceeded. Almost certainly the following year will. For airplane design is a steadily advancing science. Its triumphs of to-day are the normal performance of to-morrow. The barriers of time and distance are being constantly pushed back. We can set no limits to what the future may see.

From the point of view of everyday flying, the principal developments may be expected along three lines: the development of inexpensive private planes, the development of large transport planes, and the development of airways. At present the cheapest standard planes are priced at approximately $2,000, while the majority of low-powered, open-cockpit craft run from $3,000 to $5,000. A cabin plane will

cost from $3,000 up. These prices are, of course, prohibitive for the amateur in moderate circumstances. And in addition upkeep—hangar space, fuel, maintenance and repairs—is expensive. Millions of men who own an automobile as a matter of course have not even thought of buying an airplane. Private flying for pleasure is still distinctly a luxury.

But quantity production as exemplified in the automobile industry has not yet been tried in aviation. It was manufacturing on a large scale which originally brought automobile prices down within reach of the average man. Hence it can reasonably be anticipated that the same thing will eventually reduce the cost of an airplane. That this development will take place in the immediate future could not be safely predicted. Too many obstacles are in the way. There are not enough airports to accommodate a greatly increased number of planes. Not enough people know how to fly, and under present conditions training is expensive. And the idea of pleasure flying has been accepted only by a comparatively few people.

Some day in the future, however, we may expect to see a large number of planes produced at a relatively low cost. They will be of rugged, comparatively simple construction, and built of standard parts which can be easily replaced. Their engines will run almost without the possibility of a failure. Flying fields and hangars will be provided to accommodate them. Operating expenses will be reasonably low. Agencies throughout the country will be available to supply parts and make repairs. And instruction, scientifically organized and thorough, will be provided for purchasers at moderate rates. When that day comes, thousands of private planes will travel our skies. The airplane will become a competitor of the automobile as a pleasure vehicle.

Development in the other direction, that of commercial transportation of passengers and express, will undoubtedly bring continued increase in the size of aircraft. At present America's largest plane carries 32 passengers. But in Europe a German plane capable of carrying 160 passengers has been successfully flown. This is the Dornier Do X, an

The Fokker F-32, the largest air liner in America, has capacity of thirty-two passengers by day and sixteen berths by night. It is powered with four Pratt & Whitney Hornet motors and, in test, flew on any two of them.

enormous flying boat driven by twelve engines. Its three-decked hull is 131 feet long and contains a passenger compartment 66 feet in length, half again as long as the interior of a Pullman car. The single monoplane wing stretches 157 feet from tip to tip, more than half of a small city block. With each nine-cylinder radial engine developing

525 H.P., the total thrust amounts to 6300 H.P. These motors will take the plane into the air with a full load weight of over fifty tons and drive it at a maximum speed of 150 miles an hour. As many as four engines can be stopped for repairs at one time while the plane maintains its altitude on the other eight.

This plane, a hundred times as big as the Wright's first plane, is the giant of to-day. If the short space of twenty-six years has seen this progress, what will another twenty-six years bring forth? In imagination we can see monsters of the sky comparable in size to ocean steamers. That they may some day be actualities it would be rash to deny. No one can predict the limits of size to which our air liners will grow.

The sudden commercial development of aviation found relatively limited facilities ready to handle the new flocks of planes. Airports were few, and many were small in area. Hangars were inadequate. Airways were scarce, infrequently marked, lacking in intermediate fields and not often lighted. Much has been done to remedy these deficiencies. All important cities and many smaller ones now have large airports. These are connected by a growing network of airways. And facilities for maintenance and safeguarding of planes are being steadily developed. Air travel is becoming constantly safer and easier. This development will unquestionably continue in the future until every town has its own airport and until airways crisscross each other on the map like railways.

An interesting phase of the extension of airways is the proposed use of seadromes, one of which is already under construction. It is a large platform, 1100 feet long and 336 feet wide, designed to be anchored in the open sea where it can be used by planes as a landing field. The

platform is set on many tall, upright columns, thin and hollow, connected by bracing to insure rigidity of the structure. At the bottom these columns expand into large, hollow flotation chambers which provide the displacement necessary to sustain the weight of the seadrome. These flotation chambers are, however, far enough below the surface so that they are not affected by the force of the waves. And the upright columns hold the platform 175 feet above the surface. Thus, even in a storm, the waves would strike only the thin columns, on which they would have little effect. The flotation chambers, immersed in quiet water too deep to be affected by the wind, would not be disturbed by the surface motion. The seadrome would consequently ride steadily no matter how rough the sea became.

Experiments with models indicate that this steadiness will be secured with a full-size structure. It is therefore planned to anchor the first seadrome midway between New York and Bermuda and use it as an operating base for an airline between these two points. Amphibian planes can fly to it and land. All facilities for their maintenance will be available in a hangar immediately beneath the landing deck. Here will also be located accommodations for passengers, including rooms and a restaurant. When refueled and ready to proceed, planes will reëmbark their passengers and take off. If the first seadrome proves successful, it is believed practicable to anchor a chain of them across the Atlantic, enabling a crossing to be made by air within two days' time.

Of radically new developments in airplane design, the autogiro is the only one which at present appears to offer any indication of practicability. This machine has a fuselage of the conventional type, with an engine and propeller in the nose, landing gear beneath, and control surfaces at

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the tail. It also has a stub monoplane wing, comparatively small and insufficient in area to sustain it. Lift is supplied chiefly by the rotor, a structure comprising four large blades or vanes similar in arrangement to a four-bladed propeller. This rotor is set in an approximately horizontal plane at the top of a mast which projects upward some five or six feet

U. S. Navy Photo.

At sunset.

from the forward part of the fuselage. In flight the rotor is tipped slightly backward, so that the air flow resulting from the forward motion of the machine strikes the under surfaces of the blades at a small angle. This causes them to rotate, and their rotation provides the required lift. They are attached to the shaft in the mast by universal joints, which permit them to adjust themselves to the speed

and angle of the air flow. In order to take off, the autogiro is taxied around the field until the rotor has gained a speed of 90 r.p.m., when it will rise into the air. It will maintain its altitude at a forward speed as low as thirty miles per hour, while its maximum speed is about 90 miles. With power shut off, it will descend at a comparatively steep angle, settling level with no tendency to stall or spin. This permits a landing to be made in a much more restricted space than is required by an airplane. And the elimination of the spin precludes the possibility of loss of control from this cause. The autogiro is still in the experimental stage. But it has definite advantages which may prove of great practical value.

Unquestionably the future will see other radically new departures in the design of aircraft. What these may be and how soon they may appear, we can only guess. Adjustable wings may be developed, extensible for take-offs and landings but capable of retraction to a small span in order to permit high speeds. Perhaps some new type of engine may be evolved, many times more powerful in proportion to its weight than present models. The transmission of power by radio, permitting planes to stay up indefinitely, can at least be imagined. Or perhaps some entirely new principle of sustentation may be discovered which will enable planes to hover motionless in the air, independent of their engines. Looking back at the progress made since people smiled tolerantly at early efforts to fly, we could hardly deny the possibility that these ideas and scores of similar ones, now valuable only to the writer of fiction, may some day be translated into actualities.

But whatever new developments may mark the trend of aviation, the skies of the future will inevitably be traversed by constantly increasing swarms of aircraft. For man has

learned to use his wings. He has discovered the zest of soaring free through unbounded space. He has found the profit in swift, safe travel to distant places. He has looked down on a continent which, in terms of time, has contracted to a day's span. He has flown swiftly over hitherto unseen fastnesses in the far corners of the earth. The airplane is the last word in answer to one of his oldest longings, the desire for speed. It is a potent instrument in his unending struggle to conquer time and distance. It makes more complete his dominion over of the earth on which he lives. Therefore he will go on using his wings in an ever-increasing measure. Aviation will be an integral part of the civilization of the future.

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